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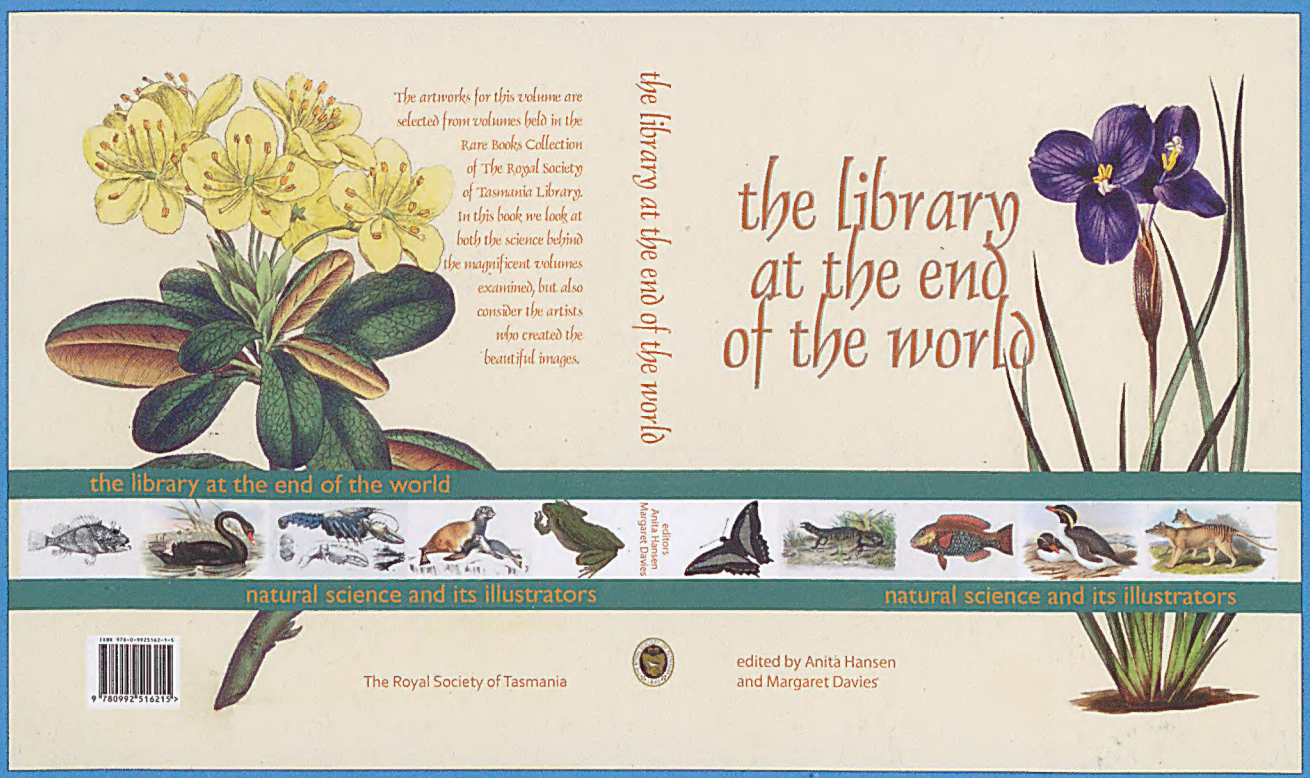
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the library at the end of the world
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The Royal Society of Tasmania
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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA

VOLUME 149

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LESS THAN 50 MILLIMETRES OF RAINFALL IN THE PREVIOUS MONTH PREDICTS FIRE IN TASMANIAN RAINFOREST

by Jennifer Styger and Jamie B. Kirkpatrick

(with two tables and two appendices)

Styger, J. & Kirkpatrick, J.B. 2015 (18:xii): Less than 50 millimetres of rainfall in the previous month predicts fire in Tasmanian rainforest. *Papers and Proceedings of the Royal Society of Tasmania* 149: 1–5. ISSN 0080-4703. Discipline of Geography and Spatial Sciences, School of Land and Food, University of Tasmania, Private Bag 78, GPO Hobart, Tasmania 7001, Australia (JS, JBK*). * Author for correspondence. Email: J.Kirkpatrick@utas.edu.au

Rainforests can be eliminated by repeated fire, so we need to know when they require protection. We use data from 11 extensive fires in western Tasmania to determine the meteorological conditions in which rainforest will burn. The variables that discriminated between fires that burned rainforest and those confined to other vegetation types were the amount of rainfall in the previous 30 days, the amount of rainfall in the previous 60 days and the soil dryness index (SDI). Our analyses confirmed a previously-suggested critical figure of 50 mm of rain in a month, showed that this figure pertains to the month previous to the fire, and showed that the forest fire danger index (FFDI) was not a good predictor, with fires burning rainforest on days with an FFDI at the lower end of the scale (Lake Macintosh) and not burning rainforest on days when the FFDI was at the higher end of the scale (Reynolds Creek and Giblin River). We conclude that it is important to respond to dry conditions in fire response planning for areas with rainforest, rather than relying on the FFDI.
Key Words: rainforest, soil dryness index, fire hazard, rainfall, forest fire danger index.

INTRODUCTION

The rainforest of western Tasmania is of world heritage significance (Balmer *et al.* 2004). Rainforest is one alternative vegetation steady state among several that occur in the region (Jackson 1968). In the absence of fire rainforest would cover all of the montane and lowland environments where the mean precipitation of the driest month exceeds 50 mm (Jackson 1968). Fire has been far from absent, so rainforest covers 700 000 ha while, in the same climatic zone, *Gymnoschoenus sphaerocephalus* (R. Br.) Hook. f. hummock sedgeland covers 600 000 ha (Marsden-Smedley 2009). The highly flammable and fire-resilient hummock sedgeland (Marsden-Smedley 2009) occurs in close proximity to the much less flammable and fire-sensitive (Jackson 1968, Wood *et al.* 2011) rainforest (Kirkpatrick 1977). Changes in anthropogenic fire regimes have resulted in rainforest becoming moorland and vice-versa (Fletcher & Thomas 2010a,b, di Folco & Kirkpatrick 2013) emphasising a need for fire management. Although fire in rainforest is uncommon (Jackson 1968, Barker 1991, Marsden-Smedley 1998, Read 2005), due to the low flammability of foliage, a humid microclimate and a low fuel load (Jackson 1968), rainforest fires can be extensive (Hill 1982, Barker 1991, Marsden-Smedley 1998, Cruz *et al.* 2012).

The McArthur Forest Fire Danger Index (FFDI) is widely used to predict fire hazard in Australian forests. It largely reflects the weather conditions on the day. Marsden-Smedley (1998) observed that the years in which five major rainforest fires occurred in southwest Tasmania all had at least one month with less than 50 mm of precipitation. Marsden-Smedley (2009) further suggested that there is moderate risk of rainforest burning when the soil dryness index (Mount 1972) exceeds 50. However, there has been no analysis of the relevance of any of these indicators of fire hazard to incidences of fire in rainforest. This understanding would allow fire managers to mobilise resources to protect rainforest in conditions under which rainforest will burn. Such an understanding will become even more important if the climate change prediction of drier summers in western Tasmania (Grose *et al.* 2010) is realised. In the present paper we use 11 well-documented fires in western Tasmania to determine the best predictors of rainforest combustion. We test the observation of Marsden-Smedley (1998) with this data set and assess whether widely accepted indicators of meteorological fire hazard can predict the loss of rainforest to fire.

METHODS

Eleven fires that burned in the southwest and west coast regions of Tasmania between 1934 and 2013 were examined: the 1933/34 fire; the Savage River fire, 1982; the Harrison's Opening fire, 1993; the Cape Sorell fire, 2001; the Mount Frankland–Donaldson fire, 2003; the Mount Castor fire, 2006; the Cracroft River fire, 2007; the Reynolds Creek fire, 2007; the Heemskirk Road fire, 2008; the Lake Mackintosh fire, 2010 and the Giblin River fire, 2013 (table 1). For each fire the FFDI and rain in the previous 10, 20, 30, 60, 100 and 365 days was determined (appendices 1 and 2).

The FFDI on the first day of the major fire run was calculated for each fire. For most fires the input data were the worst fire weather conditions to occur during that day, which was generally around 3.00 pm. This condition was assessed from the half-hourly Bureau of Meteorology data for the most relevant nearby station. For some fires, however, certain input variables have had to be estimated, taken from indirect sources, or were only available for one or two times during the day and therefore do not

TABLE 1 – Summary table of fires, amount of rainforest burned and Forest Fire Danger Index

Fire	Rainforest burned?	Percentage of rainforest burned	Area of rainforest burned (ha)	FFDI	Sources
1933/34	Y	N/A	59 364	36 (VH)	Rainfall data obtained from Bureau of Meteorology (BOM) station, Cape Sorell. Temperature and humidity data sourced from Foley (1947). Wind data used to calculate FFDI was the average of the readings reported in *The Advocate* on 10 February 1934. Drought Factor was estimated from rainfall records from Cape Sorell for the previous two months.
Savage River 1982	Y	31	15 000	57 (S)	All data sourced from Barker (1991) except wind speed data which was the 3.00 pm data from the Savage River Mine BOM station.
Harrison's Opening 1993	N	0.9	2.9	6 (M)	The Soil Dryness Index and Drought Factor were for Hobart Airport BOM station. All other data were for Geeveston (Cemetery Road) BOM station.
Cape Sorell 2001	N	2	126	4 (L)	Temperature and wind data were for Cape Sorell BOM station. Soil Dryness Index, Drought Factor and relative humidity data were for Strahan aerodrome BOM station.
Mount Frankland-Donaldson 2003	N	0.7	563	12 (H)	All data were for Luncheon Hill BOM station.
Mount Castor 2006	N	2.3	61	23 (H)	All data were for Warra BOM station.
Cracroft River 2007	N	0.9	122	23 (H)	All data were for Warra BOM station.
Reynolds Creek 2007	N	0	0	50 (S)	All data were for Scotts Peak Dam BOM station.
Heemskirk Road 2008	Y	12.9	1772	27 (VH)	All data were for Luncheon Hill BOM station.
Lake Macintosh 2010	Y	65	2201	17 (H)	Temperature, humidity and wind data were for Mount Read BOM station and temperature and humidity have been adjusted for altitude (Wolfe 1964). Soil Dryness Index and Drought Factor were for Rosebery BOM station.
Giblin River 2013	N	0.06	23	50 (S)	All data were for Scotts Peak Dam BOM station.

L = low fire danger rating; M = moderate fire danger rating; H = high fire danger rating; VH = very high fire danger rating; S = severe fire danger rating; E = extreme fire danger rating; C = catastrophic fire danger rating.

necessarily constitute the worst fire weather condition for the day. The FFDI input data were temperature, relative humidity, 10-minute average wind speed and the Drought Factor, which, in Tasmania, includes the SDI. The SDI for the most comparable nearby location on the first day of the major run was obtained from the Bureau of Meteorology (appendix 1). Although the Bureau of Meteorology now produces gridded SDI values, the paucity and poor spread of BOM stations throughout west and southwest Tasmania (Nunez *et al.* 1996), make it unlikely that these values would greatly improve the data set.

The total amount of rainforest burned for each of the Tasmanian fires, as well as the percentage of rainforest that occurred within the boundary of each fire scar, was determined using ArcMap version 10.1. The input layers were maps of fire scars produced by the Tasmanian Parks and Wildlife Service and TASVEG version 2.0 rainforest community groups, excluding RLS (*Leptospermum* with rainforest scrub). No GIS data were available for the 1933/34 fire and the distribution of rainforest within the Savage River fire boundary is likely to have changed in the three decades since the fire. In these cases, data were sourced from published literature (Marsden-Smedley (1998) for the 1933/34 fire and Barker (1991) for the Savage River fire). For the post-2005 fires it was observed that some areas classified as rainforest by TASVEG were not in fact rainforest. Pre-2005 aerial imagery was used to re-map the areas within the fire boundaries using ArcMap

version 10.1. For the Harrison's Opening, Cape Sorell and Mount Franklin–Donaldson fires, pre-1992 imagery was used for rainforest mapping. The Reynolds Creek fire burned areas mapped in TASVEG as rainforest, but this was an early successional form (J. Marsden-Smedley pers. comm. 2013), which has a higher flammability potential than mature rainforest (Uhl *et al.* 1988) and also often has a greater composition of scleromorphic species (Hill & Read 1984). Therefore, these forests were excluded from the burned rainforest area.

One-way ANOVA was used to determine whether rainforest and non-rainforest fires differed in: rainfall in the previous 10, 20, 30, 60, 100 and 365 days, SDI, Drought Factor, FFDI, temperature, relative humidity and wind speed. As the only SDI data available for the Harrison's Opening fire were from Hobart airport, which has a substantially lower rainfall than the region around Harrison's Opening, this fire was excluded from the SDI analysis.

RESULTS

Rainfall in the previous 30 days was the strongest determinant of rainforest fire, with rainfall in the previous 60 and 100 days also being significant (table 2). The SDI was the only other discriminator (table 2).

The low FFDI value for the 1933/34 fire for the amount of rainforest that was burned may be due to the high relative humidity value of 52%. It is likely that this value does not correctly represent the minimum relative humidity on 9 February 1934 for Zeehan. Climate data for the 1933/34 fire were difficult to obtain, as the Bureau of Meteorology does not have digitised records for temperature and relative humidity from any station on the west coast of Tasmania before 1957. The relative humidity datum was that reported by Foley (1947) for 3.00 pm 9 February 1934 in Zeehan. The temperature at Zeehan reached 32°C that day. It is therefore likely that the relative humidity was low, as high temperatures are not often associated with humid conditions in Tasmania (Foley 1947). It is possible that the relative humidity was only recorded at 3.00 pm, by which time a southwesterly change had already occurred, raising the humidity. If this were the case, the peak fire danger conditions would have occurred earlier in the day, when relative humidity is likely to have been much lower. Fox-Hughes (2008) reports an FFDI of 92 in Hobart for this same date. Fox-Hughes (2008) also observes that noon is the most frequent time of peak fire danger at Strahan. Considering the much higher FFDI found for Hobart for this same date and the earlier peak fire danger found to frequently occur on the west coast, it is most likely that the peak FFDI for the west coast was much higher than reported by Foley (1947).

The Lake Mackintosh fire had the largest percentage of burned rainforest of the 11 fires (table 1). The FFDI reached only 17. This was the lowest FFDI of any of the fires that burned rainforest. The temperature, humidity and wind speed data used to calculate the FFDI were recorded at the Mount Read weather station, which occurs at an elevation of 1 120 m a.s.l., some 900 m higher than Lake Mackintosh. However, as the temperature and humidity data were adjusted to take into account the global mean environmental lapse rate, the FFDI value should be close to accurate for the area around Lake Mackintosh. Indeed, as wind speed was unadjusted, and is likely to be greater at higher elevations, it is likely that our FFDI value may be higher than reality.

The Savage River fire burned the largest area of rainforest of any of the post-1930s fires, at 15 000 ha. The fire is reported to have burned mostly implicate and thamnic rainforest (Barker 1991). Implicate rainforests tend to occur in cooler and more humid environments than callidendrous rainforests. This environment is likely to reduce fire incidence. However, the high fuel load and continuous fuel ladder from the forest floor to the canopy of implicate

TABLE 2 – Significance of climatic differences between fires that burned rainforest and those that did not (one way ANOVA)

Variable	F-value	P-value
Rainfall in previous 10 days	0.93	0.360
Rainfall in previous 20 days	2.83	0.127
Rainfall in previous 30 days	14.33	0.004
Rainfall in previous 60 days	6.39	0.032
Rainfall in previous 100 days	3.74	0.085
Rainfall in previous 365 days	0.07	0.796
Soil Dryness Index (excludes Harrison's Opening fire)	7.25	0.031
Drought Factor	3.90	0.080
Temperature	1.00	0.344
Relative humidity	0.29	0.601
Wind speed	0.02	0.901
Forest Fire Danger Index	0.73	0.415

rainforests may make them more likely to carry intense fire once dry than the cathedral-like callidendrous forests.

The Giblin River fire had the most extreme weather conditions of all Tasmanian fires, except the Savage River fire. However, as apparent from aerial photography and personal observation by one of the authors (JBK) from a helicopter in 2014, the Giblin River fire burned mostly buttongrass, with rainforest, eucalypt forest and even scrub remaining largely unburned. Although the temperature, humidity and wind associated with this fire were all extreme, the wetness of the forest floor prevented burning.

DISCUSSION

Our results both confirm and modify the observation of Marsden-Smedley (1998) that a month with less than 50 mm of rain characterised the five years with most extensive recent fires in Tasmania. All the fires in which rainforest burned were preceded by a 30-day period with less than 50 mm of rain. Conversely, all the fires in which rainforest did not burn were preceded by a 30-day period in which rainfall exceeded 50 mm (appendix 2). Thus, it is not the occurrence of a dry month in a year, but rather the occurrence of a dry month immediately preceding ignition that allows fire to penetrate rainforest, with weather conditions on the day of ignition being almost irrelevant.

The main practical implication of our work is the obvious need to declare fire bans, and take strong precautions, when the rainfall total for the previous month falls below 50 mm, as well as on days of high fire danger as judged by the SDI and FFDI. It is in these rainfall deficit conditions that response planning to protect remote rainforest should take place. When FFDI is high and there has been more than 50 mm of rain in the previous month, response planning should focus on the protection of alpine areas, rather than rainforest. A second implication is the importance of establishing a more representative and even network of meteorological stations than presently exists in the wilderness areas of western Tasmania.

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(accepted 6 October 2015)

APPENDIX 1 – Input variables for calculating the Forest Fire Danger Index for each fire

Fire	Temp. (°C)	Relative humidity (%)	Wind speed (km/h)	Drought factor	Soil Dryness Index	Time of readings
1933/34	32	52	80	9	N/A	RH data from 3.00pm. Other data unknown
Savage River 1982	34	9	34	9	64	Wind speed from 3.00 pm. Other data unknown.
Harrison's Opening 1993	14	58	33.5	9.3	102	3.00 pm
Cape Sorell 2001	18	62	31	6.5	30	12.00 pm
Mount Frankland-Donaldson 2003	23	36	37	6.6	26	12.00 pm
Mount Castor 2006	34	29	35	7.2	36	3.30 pm
Cracroft River 2007	32	24	28	7.4	39	2.00 pm
Reynolds Creek 2007	34	22	54	7.8	48	3.00 pm
Heemskirk Road 2008	31	26	30	9.5	99	3.30 pm
Lake Macintosh 2010	28	34	35	7.4	40	2.45 pm
Giblin River 2013	33	22	83	4	15	4.00 pm

APPENDIX 2 – Rainfall values for different time periods preceding each fire

Fire	Rainfall (mm)					
	10 days	20 days	30 days	60 days	100 days	365 days
1933/34	16	30.7	34.1	72.6	127	1100
Harrison's Opening	33.4	51.6	66.4	156.8	204.8	684.4
Cape Sorell	7.6	58.8	69.6	78.6	101.85	1030
Mount Frankland-Donaldson	2	36.8	115	310.2	597.8	1569.6
Mount Castor	6.6	32.6	167.2	332.6	519.2	1671
Cracroft River	4.2	27.8	102.8	193	342.8	1738
Reynolds Creek	0.6	25.8	135.4	262.4	392	1572
Heemskirk Road	0	5.2	47.8	66.6	81.6	1356.6
Lake Mackintosh	2	31.2	36.8	168	238.4	1845.4
Giblin River	39.6	107.6	144.4	249.4	468.4	2067

THE MYSTERY OF THE K. PRENDERGAST MANUSCRIPT

by Don Squires, Michael J. Clarke and Sandra Freshney

Squires, D., Clarke, M.J. & Freshney, S. 2015 (18:xii): The mystery of the K. Prendergast manuscript. Papers *and Proceedings of the Royal Society of Tasmania* 149: 7-12. ISSN 0080-4703. Tasmanian Museum and Art Gallery, Hobart, Tasmania 7001, Australia (DS*, MJC), and Sedgwick Museum of Earth Sciences, Brighton Building, Cambridge, England CB3 GEI (SF). *Author for correspondence. Email: squiresdon27@gmail.com

In the 1930s a rising star in the constellation of Australian palaeontologists had been born. Hard working, attentive to detail and very bright, Kathleen Laura Prendergast seemed destined to attain a solid place in the high ranks of Australian geology. Winner of many awards and scholarships, she carried her academic career through to a PhD at Cambridge University. Then, abruptly her course changed and in a relatively brief time she gained an MD and served as a medical officer in the British Army. Left behind as a consequence of that career change were a manuscript and her research collections, the former seemingly important, possibly even critical to an evolving understanding of Permian brachiopods. That manuscript was thought to have been commenced, possibly finished, but then lost through misadventure. The star collapsed, but a myth remained. This paper is the result of an exploration of the trajectory of the career of Kathleen Prendergast. It attempts to resolve the story of the "lost" manuscript and an analysis of what might have been. This investigation involved The Royal Society of Tasmania and the Tasmanian Museum and Art Gallery, the Sedgwick Museum of Earth Sciences, Cambridge University, the Royal Society of Western Australia and the University of Western Australia amongst others.

Key Words: Permian brachiopods, Prendergast, Western Australia, Tasmania, Cambridge, England, *Taeniothaerus subquadratus*.

THE STORY

Kathleen Laura Prendergast was born in Carlton, Victoria, on 19 November 1910 to Mary Jane Fisher (née Betharas) and George Lucas Prendergast. A second daughter, Mary Betharas Prendergast, was born a year later. According to electoral records, the family moved about. In 1914, they lived in Black Rock, Victoria, where George was listed as a farmer. After his discharge from the military in 1919, the family is listed as living in Cheltenham. In the 1925 Electoral Roll, Kathleen's mother, Mary Fisher, appeared as a teacher in Maylands, Perth, Western Australia, and again in 1931 at Nedlands, Freemantle. George Lucas Prendergast died in 1932 in Perth. In the 1936 roll the two daughters, Kathleen Laura and Mary Betharas were living in Freemantle with their mother, who died in 1949 in St Kilda, Victoria (Glover 2013).

Kathleen Prendergast's first expressed career interest was the study of medicine, but when the opportunity for tertiary education at the University of Western Australia came to her, she selected geology as her field of study.

She graduated in 1933 as a BSc with Honours. During her Honours year she did palaeontological consulting work for the Freney Kimberley Oil Company then exploring the region of Permian outcrop in Western Australia. She had already gained a reputation for energetic and able work, but she was unable to get full-time employment in geology involving fieldwork, a not unusual situation for a woman in the early twentieth century. As an alternative to geological work, she considered teaching as a means of enhancing her and her family's income (Glover 2013).

Kathleen qualified for the Diploma of Education in 1935. That same year she was awarded a Hackett Research Studentship for the study of "The Permo-Carboniferous fauna of Western Australia". After spending the first year at the University of Western Australia she requested and was granted a suspension for a year (about 1936) so that she could work as palaeontologist for the Freney Kimberley Oil Company. In 1937 she went to Cambridge University to complete her academic studies in palaeontology. In her first year she was awarded a scholarship by the Royal Commission for the Exhibition of 1851 which would provide monetary support for an additional two years. She was only the second graduate of the University of Western Australia to gain this honour (Anon 1937).

Why was Kathleen Prendergast stirring so much interest on her behalf?: "Miss Prendergast impresses with the work she is doing. She has undertaken a difficult job which demands infinite care, insight and patience. These qualities she undoubtedly possesses... It would be little short of a scientific calamity if so able a person were not allowed sufficient time to make fullest use of her opportunities" ("an outstanding Professor of Geology at Cambridge" [probably Owen Thomas Jones FRS, Woodwardian Professor at Cambridge, 1930–1943], Anon 1937, p.12).

In her 1935 Honours paper (Prendergast 1935) she described and figured 12 genera, one of which was new and ten species, four of which were new. Her descriptions were detailed, but she made no revisions of the taxonomy other than to note that many geologists were content to list fossil fauna of strata by pre-existing names without review. She revised incorrect but oft-repeated fossil identifications by geologists: as she put it poetically, but rather acidly, it was about:

> *[Some]... Creatures borrowed and again conveyed From book to book – the shadows of a shade.* (Prendergast 1943, p.1)

In 1943 she published a longer paper, "Permian Productinae and Strophalosinae of Western Australia" (Prendergast 1943). This study, drawing on the expanded collections she had made while working with the Freney Kimberley Oil Co. and loans from various museums, not

only broadened knowledge of the variety of the brachiopod fauna but, again, was critical of previous authors for simply using established names for the taxa. Further she amplified the morphological descriptions of many species particularly emphasising the character of the internal structures of the brachiopods which she illustrated with drawings. This work covered ten genera of the families considered, none of which were new. Twenty-seven species were described, seven of which were new. This research was, in our estimate, the basis for her PhD. dissertation. A copy of Prendergast's dissertation was not available to us for comparison. Our judgement is based upon the time of publication and comments, in passing, of her colleagues in Western Australia.

CHANGE OF COURSE

Following award of her PhD in 1939, Prendergast seemed to have planned to continue her research on the Permian brachiopods of Australia. She was supported in this endeavour by the funds from the 1851 Royal Commission scholarship. Rather than simply adding to her substantial contributions to the Western Australia Permian fauna, she obtained specimens from the Permian strata of Tasmania from several sources including the Tasmanian Museum and Art Gallery (TMAG). Her intention was signalled by a note in her 1943 paper. Following the brief diagnosis of the genus *Taeniothaerus,* she referred readers to an as yet unwritten paper:

> *For a description of this genus see Prendergast, Proc. Roy. Soc. Tasmania* (Prendergast 1943, p.27).

Although she was still thinking about her future research, other, seemingly more pressing matters were occupying her time and priorities. Sometime after 1939 Prendergast ceased her palaeontological research and commenced training in medicine culminating in a medical degree and certification in 1944. We can only speculate on her motivation. Some of the brief biographies appearing in the media after her death suggest this was a reversion to her earliest interests in medicine, while others have suggested that she may have wished to serve England in the latter days of World War II. Whatever the reason for this change, upon completion of her medical certification she was appointed to the British Army of the Rhine (BAOR), with the rank of captain. Soon thereafter she was assigned as Resident Medical Officer (RMO), with the rank of major, to the Black Watch Regiment (BAOR). This was the first ever RMO appointment to a serving military unit made to a female by the British Army and the first ever to the Black Watch. While many thought that the placement of a female in that unit of such rugged reputation was a joke, the commander of the regiment rejected such thoughts and resisted attempts by the Army Medical Corps to reassign her elsewhere. Colonel Bernard Ferguson, regimental commanding officer, said of her: "... she wove herself quickly into the regimental fabric ... and became expert in regimental programs" (Glover 2013, p.7). This was substantiated by her being permitted to wear the "Red Hackle" in her bonnet as were other "outstanding personnel" (Glover, 2013, p.7).

Upon de-mobilisation in the autumn of 1953, Major Kathleen Prendergast was posted to the Cowgden Military Hospital in Glasgow and died, seven months later, on 1 June 1954, of sarcoma of the lung (Statutory Deaths 644/18/05321 provided by scotlandspeople@ gro-scotland. gst.gov.uk). She is buried at the hospital cemetery.

THE RESEARCH SHE LEFT BEHIND

Before Prendergast left the field of palaeontology, she had begun to acquire the materials for what would be her third study of the strophalosid and productid brachiopods of Australia. It would have commenced about 1939–1940. She had undoubtedly seen some of the eastern Australian and/or Tasmanian specimens in the Sedgwick Museum at Cambridge and would use them to resolve issues that had troubled her in her doctoral studies (Hill 1950).

But she would require an expanded collection. There is no evidence that Kathleen had ever visited Tasmania, Victoria or eastern New South Wales. How and who she contacted in Tasmania to arrange for those additional materials has been more clearly defined by our investigations but there is little direct evidence of how those contacts commenced. It is probable that her professor at Western Australia was known especially through the royal societies of Western Australia and Tasmania. But, at that time geology was in a formative stage in Tasmania. The Tasmanian Museum and Art Gallery had yet to appoint a curator of geology and its collections were limited in scope. The University of Tasmania's Geology Department was only formed in 1947 (Jennings 1990) and the Geological Survey of Tasmania, initiated about 1900, was in "sorry condition" until about 1954 (Jennings 1976, p.76). Tasmanian geological studies were being undertaken largely by self-taught amateurs, often operating under the aegis of The Royal Society of Tasmania. Many of these amateurs displayed great talent. One such, a lawyer by formal training, but with a great interest in geology, was Arndell Neil Lewis, who had informal relationships to both the university and the museum. Lewis (1897–1943), born in Symmons Plains, Perth, Tasmania, was an avid naturalist, particularly of geology. He published 18 papers on the subject in the *Papers and Proceedings of the Royal Society of Tasmania*, was awarded the Society's Medal in 1935, and his memorial volume, *The Geology of the Hobart District* was published in 1946 by The Royal Society of Tasmania with public support. He was Lecturer in Geology at the University of Tasmania from 1927–1931 and active at that time at the Tasmanian Museum. He married Amy Stewart Hungerford in 1927. We believe that through Lewis's participation, the Tasmanian Museum and Art Gallery made the first loan to the Sedgwick Museum for Prendergast's study. That Lewis himself made a subsequent loan from his personal collection to Kathleen Prendergast is well documented by a letter from A.G. Brighton, Sedgwick Museum, to Mr. E.C. Lewis, Hobart, dated 23 May 1947:

> *I gather from a letter I have received from the Director of the Tasmanian Museum that all the specimens, whatever the labels, were collected by Dr. Lewis* (Brighton 1947a).

The number of specimens and their identification marks in each of these loans is not known as no records were made or preserved by the Tasmanian Museum and Art Gallery. However, the much later return of the specimens to their rightful owners, while presenting a substantial problem for Sedgwick Museum Curator Professor A.G. Brighton (1900–1988), known as Bertie throughout his professional life, resulted in a detailed accounting of the specimens being returned:

From the Tasmanian Museum:	37	specimens
From A.N. Lewis:	47	specimens
From "Lewis's Last Collection":	10	specimens
No label of ownership:	40	specimens

The phrase "Lewis's Last Collection" refers, we believe, to a collection amplifying those previously sent by Lewis, for it notably contained the best specimens of the productid *Taeniothaerus*. There had been communication between Prendergast and Lewis about the need for better and/or more specimens, especially productiid Brachiopods, only a few of which had been included in the earlier loans. Of the 37 specimens listed as Tasmanian Museum, only ten were other than strophalosids. Some of the Lewis collection specimens may have been transferred by Mrs Amy S. Lewis or H.C. Lewis (A.N. Lewis's brother) to the Tasmanian Museum and Art Gallery.

Freed from the pressure to prepare her doctoral dissertation for publication and preceding the onset of her medical studies, Kathleen completed her research on the Tasmanian specimens. We have evidence of this through specimens returned to the Tasmanian Museum and Art gallery marked as "figured" or "type" and by fragments of the manuscript known as the "Mystery Manuscript" or "The Lost at Sea Paper" (see below). That Prendergast believed she had completed this research and fulfilled her obligations to those who had provided the study materials is contained in her description of *Taeniothaerus* in her 1943 paper. Prendergast stated, under *Remarks*:

> *For description of this genus see Prendergast, Proc. Roy. Soc. Tasmania.* (Prendergast 1943, p.27).

That statement is a clear indication that the author has done the research; the manuscript with its descriptions and conclusions has been written and dispatched to Professor E. de C. Clarke, her mentor while at the University of Western Australia. Kathleen was apparently expecting Clarke to forward the manuscript to The Royal Society of Tasmania. But the latter steps of the process were conducted under constraint. Kathleen was busy with her medical studies. She apparently didn't fully inform Professor Clarke of her completion of the manuscript or when it was actually sent to him. Several years after it could be reasonably expected that the manuscript had arrived and been processed, it was still missing.

On 19 March 1947, A.G. Brighton wrote to E. de C. Clarke asking if the Prendergast manuscript had been published in Western Australia. This was an adequate passage of time for the publication to have completed (Brighton 1947 b). Clarke wrote back explaining that while Prendergast had sent three copies of the manuscript…"only the last of which reached us and that was devoid of title and plates" (de C. Clarke 1947). Thus evolved the "Mystery of the Lost Manuscript".

What is not explained is why E. de C. Clarke did not inform J. Pearson, director of the Tasmanian Museum and Art Gallery, and member of The Royal Society of Tasmania, of the arrival of the manuscript unless he was expecting a second shipment from Kathleen. That task was left to A.G. Brighton who wrote to Pearson in a letter dated 23 May 1947 (Brighton 1947c) that:

> *…such portions of the MS. of her paper written for the Proc.Roy.Soc. [sic] Tasmania as managed to survive the war risks of the voyage to Australia. I enclose also this manuscript. I note from it that the specimen labelled* Taeniothaerus subquadratus *(Morris). Topotype. P. 16 [sic](see p.7 of MSS.) was originally sent her by Dr. Lewis, and I think it must be the particular specimen about which Mrs. A.S. Lewis was enquiring when she visited us last year.*

THE PRENDERGAST MYSTERY RE-EMERGES

In June 1946 the Sedgwick Museum was re-awakened to the matters of Kathleen Prendergast's departure. In a letter to Kathleen, A.G. Brighton reported that, in the course of cleaning out space in the attic:

> *…three trays of your material, the labelled part of which belongs to the Tasmanian Museum and formed I presume the basis for your paper which is in the process of being published by the Tasmanian Royal Society... What shall I do with the stuff?* (Brighton 1946).

It was suggested that on her next leave she might visit Cambridge and deal with the materials. On 26 July 1947, Bertie again wrote:

> *We wrote about the specimens mentioned on 13th June 1946 [a year previously] and mentioned the visit of Mrs. A.S. Lewis. Having had no answer from you so ...wrote to the Tasmanian Museum, Professor E. de C. Clarke and the Western Australian Geological Survey and sent back all your 'stuff'. As far as I know this effectively deals with all the material, but I should be glad to have your opinion* (Brighton 1947d).

A handwritten letter from Kathleen Prendergast to A.G. Brighton dated 20 July 1947 opens with an expression of surprise that she should have received a letter dated 13 June 1/76 which she presumed was an error on the part of the author. Whether the year delay in her knowledge of the letter was inattention on her part or the often experienced delays in mail delivery as posting of personnel changed is not known. But Kathleen continued that "… an anticipated leave in September would be a good time to come up to ~~Australia~~ [sic] Cambridge" (Prendergast 1947).This is suggestive of Kathleen's awareness of her impending visit to Australia but which to our knowledge did not involve a stop at Cambridge. Kathleen's visit occurred in July 1949 and was reported in the *Argus* (*Argus*, Melbourne 1949) as a … "flying visit […] from [Duisburg] Germany, where she is [in a] Black Watch Highland Regiment". The article

largely concerned her initial opinion of Australian males and her shopping plans. It is quite possible that Kathleen also visited her mother then living in a suburb of Melbourne.

From November 1946 until November 1947 there was a flurry of correspondence between A.G. Brighton, Sedgwick Museum, Joseph Pearson, Director Tasmanian Museum and Art Gallery, Mrs A.S. Lewis and Mr H.C. Lewis, both of Hobart, regarding the "disposition of the Tasmanian fossils which had been sent to Kathleen Prendergast for her studies". The archives of the Sedgwick Museum yielded 14 letters, none of which have appeared in the files of the Tasmanian Museum or of The Royal Society of Tasmania.

An additional correspondence of five letters between E. de C. Clarke, University of Western Australia, with the Director, Geological Survey of Western Australia, dealt with the disposition of specimens from the Prendergast collection. But even with this effort there were a substantial number of specimens left over and which were possibly, but not certainly, sent to the University of Western Australia.

CONNECTING THE TASMANIAN MUSEUM AND ART GALLERY TO KATHLEEN PRENDERGAST

In 1967 Michael Clarke was newly arrived in Australia from Ireland to his appointment as the first palaeontologist for the Geological Survey, Tasmanian Department of Mines. One of his first assignments was in the Quamby map area in northern Tasmania and was the commencement of a 26+-year career of interpreting the stratigraphy and palaeontology of the Upper Carboniferous and Permian sedimentary rock series of Tasmania. While monitoring a bore hole in Quamby Brook area, he searched in Quamby Brook exposures and encountered a new and exceptional display of strophalosid brachiopods which would serve as a marker in the Early Permian strata of Tasmania. To document this faunule, he produced a monographic treatment of their taxonomy (Clarke 1969).

Being new to the country, he had not yet developed his own collection and was using, in part, reference specimens from the Tasmanian Museum and the Geology Department, University of Tasmania. Among the specimens from the Tasmanian Museum were several bearing both the Tasmanian Museum registration numbers (Z####) and paper stickers marked PL##. With one of those specimens was a small paper label stating that the specimens marked with the PL sticker had been identified by K. Prendergast. The name Prendergast was unknown to most Tasmanian geologists, but the spectre of an unpublished manuscript was interesting to Clarke. Was it unpublished, or just forgotten? If found, what matters might it contain that would present problems to later researchers? Clarke (1969) with the outstanding Quamby Brook strophalosid collection now in hand, reviewed in detail the tangled systematic history of the Australasian strophalosids. In so doing he pre-empted the problems that would emerge with publication of Prendergast's 1953 paper.

Michael Clarke's next encounter with the name K. Prendergast occurred later while he was reviewing P.J. Coleman's 1957 study of the Permian Productacea of Western Australia. In that paper, Coleman (1957) reviewed the taxonomy of the Productacea citing K. Prendergast's previous works. Michael Clarke, who had not previously seen the Prendergast studies (and did not until 2013), only remembers Coleman's work in passing. Twenty years later, retired from the Department of Mines and now an Honorary Research Scientist at the Tasmanian Museum and Art Gallery, Clarke was reviewing the Tasmania Museum's early acquisitions of Permian brachiopods. His remarkable memory for detail intact, he recalled seeing among those specimens some similar to those seen nearly 30 years earlier which bore the paper tag notation P## and a label citing a pending Prendergast manuscript.

The original papers regarding the loan of specimens made to Dr Prendergast at the Sedgwick Museum following completion of her PhD. work had not been preserved at the Tasmanian Museum and Art Gallery, but the Sedgwick Museum records detailed it when the specimens were returned in 1947. In a letter from A.G. Brighton to J. Pearson dated 23 May 1947. Brighton details what he had done in the distribution of specimens comprising the Prendergast loans, especially those of the "Lewis Collection". He confirms that E. de C. Clarke had sent "such portions of the MS written for the Proc. Roy.Soc [sic] Tasmania as managed to survive the war risks of the voyage to Australia" to him. He then raises the question of the specimen of *Taeniothaerus* marked "topotype" sought by Mrs. Amy Lewis. Importantly he notes that it appears on p.7 of the manuscript. Brighton also enclosed a one page comprehensive listing of the specimens borrowed by Prendergast now returned to the Tasmanian Museum (Brighton 1947e).

Surprisingly, the document accompanying the specimens returned by the Sedgwick Museum contained a listing of "Specimens associated with the above, but not definitely labelled Tasmanian Museum". The new material from the east coast of Tasmania, suddenly broadened Prendergast's view of the Permian brachiopod fauna which, until then, had been of Western Australia only. It presented some interesting and puzzling new information. While M. Clarke had dealt with the strophalosids, there was a greater problem with the productiid *Taeniothaerus.*

Taeniothaerus is a genus of productid brachiopod found in the Lower and Mid-Permian strata of Australia with a more restricted range of occurrence in other countries. It was first described by Morris in 1845 based on specimens collected by Count P.E. Strzelecki in 1845 (Morris 1845). As is the case with many of these early collections in Tasmania, the actual site of collection is poorly described and the specimens were of indifferent quality. As a consequence, descriptions of these new genera and species were often brief. Attempts at re-collection often resulted in broadened misunderstandings of the taxa resulting in confusion and misuse of the names. Such was the instance with *Taeniothaerus* and its type species.

In 1928 F.W. Whitehouse proposed a new genus

Taeniothaerus for a brachiopod based upon the nominated type species *Productus subquadratus* Morris, but he neither described nor figured the genus or species. Prendergast seized upon this and declared *Taeniothaerus* a *nomen nudum* (Prendergast 1935, p.17, footnote 1). This could have been well but for the International Rules of Zoological Nomenclature which permit the creation of a new genus without definition or illustration as long as a type species is nominated. This rather vague situation is how matters stood in late 1933.

Prendergast (1943) revisited the issue of *Taeniothaerus* giving a diagnosis of the genus and a description of its type species, *T. subquadratus* (Morris). While little is said of her previous convictions, she did note that in a stratigraphic sequence from the Fossil Beds, Irwin River, Western Australia, *T. subquadratus* might be a transitional form between *Aulosteges baracoodensis* and an unknown *Productus*. Then Prendergast (1943) described a new species *Waagenoconcha imperfecta* with "'*Productus subquadratus*' *Morris, Chapman, p.36*" as a synonym.

THE "LOST AT SEA" MANUSCRIPT APPEARS

In 1950, P.J. Coleman, Senior Research Fellow, Geology Department, University of West Australia, wrote to the Sedgwick Museum (Coleman 1950) asking about the Prendergast manuscript "lost at sea during the war". A.G. Brighton (1950) responded that the "very incomplete" manuscript was at the Tasmanian Museum. Coleman then addressed the matter to the Tasmanian Museum with the following result:

> *Through the courtesy, of the Director of the Tasmanian Museum I have been able to study a rough draft of the lost paper, which confirms the diagnosis given. Because this draft may not have been the final expression of opinion, I do not feel at liberty to pass on any other results of her work, except to say that it does confirm the difficulty involved in the re-study of the type species, caused by the above complications.* (Coleman 1950 p.85)

Coleman (1957) discusses *Taeniothaerus* and repeats Prendergast's conclusions. On p.86 he discusses her problems with the "poorly preserved" specimens of Western Australia and the broad [implied] use of descriptions of *subquadratus* by authors from Queensland and New South Wales. He then states:

> *Prendergast was able to procure additional material from the general locality given for the original specimens of subquadratus [The Lewis collection]. On the basis of this she completed her study and gave the diagnosis given above [that of Prendergast 1943, p.27]. Most unfortunately the manuscript containing the results of this work was while in transit to the Royal Society of Tasmania lost at sea during the last world war. She had, however, incorporated the diagnosis of* Taeniothaerus *in another paper (Prendergast 1943).*

Dorothy Hill (1950) made substantive corrective actions to the taxonomy of *Taeniothaerus* though she considered it a subgenus of *Aulosteges*. She illustrated (photographically) for the first time, the type specimen of *Productus subquadratus* Morris lodged in the British Museum (Natural History), and, she gave the type locality of *T. subquadratus* more definitively than the "Tasmania", which the Lectotype [BM(NH) specimen 91171] was labelled. She also quotes A.N. Lewis's maps as suggesting that the Strzelecki locality was probably the fossiliferous limestones outcropping about the Glenorchy reservoir (Hill 1950, p.7).

But, it was not until Susan Parfrey's 1983 study that *Taeniothaerus* was completely understood. She wrote:

> *Previous descriptions of* T. subquadratus *(Morris) have not been based on the type specimens, but were made from material collected elsewhere in Australia and considered to be* T. subquadratus. *(Parfrey 1983, p.290).*

She continues with a new and detailed description based upon both collections from type localities and on excellent specimens from new Tasmanian localities, such as the Enstone Park Limestone at Elephant Pass, the Peter Limestone at Friendly Beaches and Counsel Creek Formation at Maria Island. Some of the numerous specimens depicted are also ones studied by Prendergast: Figure 2A,B,D, Figure 3D, Figure 4.

A FINAL NOTE

Much has been learned about the "Prendergast Mystery" in the course of this investigation, but not all has been resolved:

1. The missing ("Lost at Sea") manuscript is still missing. But it has been tracked from its war-time trans-Atlantic crossing to Nedlands, Western Australia, and through shipments from the University of Western Australia back across the Atlantic to the Sedgwick Museum, and again to the Tasmanian Museum and Art Gallery and to the University of Sydney and then who knows. The last resting place of that "fragmentary MSS" may be at Sydney (if P.J. Coleman failed to return it), or at the Tasmanian Museum and Art Gallery (if he did). However, the questions raised by its being "missing" have largely been resolved.

2. The specimen of *Taeniothaerus subquadratus* (Morris) sought by the Lewis family was sent to the Tasmanian Museum and duly registered as specimen Z217 in one of its catalogues. It is quite probable that the specimen was later retrieved by either A.S. or H.C. Lewis from among the specimens returned from the Sedgwick Museum as had been suggested by Director Pearson. The specimen has not been located in the museum's collections. But the absence of a card with that number in the card catalogue started in or about 1935 by Dr Maxwell Banks, who when newly appointed to the Geology Department, University of Tasmania, also worked, part-time, as the first to curate the palaeontology collection, Tasmanian Museum, is taken as an absence of the specimen in the collection. If that is so, the specimen is now either in the possession of a Lewis family member or misplaced.

But the story of Kathleen Prendergast has been told in its entirety and the myths associated dispelled.

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HISTORICAL ECOLOGY: A CRITIQUE OF FRANÇOIS PÉRON'S ACCOUNT OF SOUTHERN ELEPHANT SEALS, *MIROUNGA LEONINA* (LINN.), AT KING ISLAND, BASS STRAIT, IN 1802

by John K. Ling

(with one text-figure and two plates)

Ling, J.K. 2015: (18:xii). Historical ecology: a critique of François Péron's account of Southern Elephant Seals, *Mirounga leonina* (Linn.), at King Island, Bass Strait, in 1802. *Papers and Proceedings of the Royal Society of Tasmania* 149: 13–21. ISSN 0080-4703. 4 Links Road, Novar Gardens, South Australia 5040, Australia. Email: jpling@sa.chariot.net.au

François Péron's quite detailed observations of Southern Elephant Seals, *Mirounga leonina* (Linn.), at King Island, Tasmania, in December 1802, are considered in the light of current knowledge of this species. Acute observations of the elephant seal and its behaviour, as well as remarks about its life history, which appears to have differed slightly from that observed recently at sub-Antarctic Macquarie Island, the nearest current breeding site, were recorded. There is a suggestion that the breeding season at King Island may have been earlier than where Southern Elephant Seals now occur in the sub-Antarctic, possibly due to King Island being closer to the equator. Péron noted that Aborigines at Port Jackson called them *Mirourong*, from which their current generic name was derived, and they still frequent this coast. He does not mention seeing small immature elephant seals at King Island in December when this age class hauls out to moult on Macquarie Island. The presence then of (probably exaggeratedly) large males again suggests that the annual cycle at King Island may have been in advance of that observed at Macquarie Island today. Péron's growth rates were far in excess of those now known for the species anywhere: how he arrived at them he does not record; possibly this and other information was related to him by the sealers.

Key Words: Historical ecology, François Péron, Southern Elephant Seals, *Mirounga leonina*, King Island.

INTRODUCTION

Much biological (and anthropological) information can be gleaned from the writings of early explorers and navigators, as well as the secondary works of modern historians studying human history based on exhaustive study of many kinds of old (primary) sources of information. Careful extraction and analysis of facts and figures from these sources by trained biologists may allow the synthesis of very useful information about the early ecology and natural history of a particular area or biota which can be compared with contemporary knowledge. Quite often, statistical data collated from old accounts and catch records may then be applied to quantitative analysis of, for example, past animal populations and the effects on them of human exploitation (see Hindell & Burton 1988, Ling 1999a, b, 2002) to assist in stock analyses.

This discipline has been labelled historical ecology or ecological history (Lunney *et al.* 1999, Ling 2007). Holm *et al.* (2001, p. XIII) broadened its name to environmental history and its scope to "the integrated analysis of ecosytems and human societies, in particular the place of humankind in the historical development of ecosystems", such as the effects of human exploitation of natural resources and land development. Historical ecology does not go as far back in time as palaeoecology, which relies on markers such as fossils, sediments, rocks and ice cores for its interpretation.

The current study is a further example of its application. It aims to compare observations of Southern Elephant Seals, *Mirounga leonina* (Linn.), at King Island, Tasmania (40°S, 144°E) (fig. 1), in 1802 with what we know about the species today.

François Péron was the naturalist aboard *Le Géographe*, the lead ship of Captain Nicholas Baudin's "voyage of discovery to southern lands", 1800–1804. In France he studied medicine and was appointed trainee zoologist to the expedition on the recommendation of the great anatomist and zoologist Georges Cuvier. The expedition carried two artists, Charles-Alexander Lesueur and Nicholas M. Petit.

Péron was commissioned to write the official narrative account of the expedition upon its return to France. The first volume, comprising chapters I to XXI, was completed and published in 1807 after the death of Baudin (Péron 1807), and an English translation appeared just two years later (Péron 1809) a year before Péron died, possibly to capitalise on the British interest in what France was up to in those days (see Fornasiero & West-Sooby 2014). Louis de Freycinet, the expedition's cartographer, completed the second volume, chapters XXII to XXXIV (Péron & Freycinet 1816). Helen Micco (1971) translated chapters XXII and XXIII of this edition. These early works were subsequently revised by Freycinet and published as two volumes (Péron & Freycinet 1824). The first English translation of this edition was published recently in two volumes by the Friends of the State Library of South Australia. Because there never had been an English version of Volume II published in its entirety, it was produced first (Péron & Freycinet 2003), followed by Volume I (Péron & Freycinet 2009). These superb new translations by Christine Cornell will allow many more scholars of various disciplines to have access to early observations on natural history (and anthropology) in the Indo-Pacific region than hitherto, when only the French texts were available.

FIG. 1. — King Island showing, among others, places mentioned in the text. Councillor Island (previously known as Sea Elephant Rock) is shown, but not named, just below the words Pt Cowper on the eastern side of the island. Shell Company of Australia, reproduced with permission.

The expedition stopped off at King Island at the western end of Bass Strait from 6–28 December 1802, during which period Péron spent a considerable time ashore observing its natural history in general and Southern Elephant Seals in particular; he also described the sealing industry at the time of his visit (Péron & Freycinet 2003). When the naturalists arrived they found the sealers' camp set up on a hilltop at the northern end of Sea Elephant Bay (see pl. 1A); so they established their base at the head of the bay about six miles (9.5 kilometres) southward (see pl. 1B), near Fraser Bluff, and where the small township of Naracoopa is now situated. Plate 4 in Micco (1971) depicts a sketch by one of the expedition's artists, Nicholas M. Petit, of the French scientists' camp at Sea Elephant Bay. According to Michael Crow (pers. comm. 2012), no archaeological evidence from the Frenchmens' visit has ever been found, despite concerted efforts by members of the King Island Historical Society to locate any relevant material.

DISCOVERY AND NAMING OF THE SOUTHERN ELEPHANT SEAL

Péron's account includes what is possibly one of the earliest, if not the first, of many detailed descriptions of the intensively studied elephant seal's life history. Péron writes of his own quite acute observations as well as those related to him by the sealers who had already spent the previous 13 months on King Island prosecuting their industry and where they were able to record – probably only mentally – the Southern Elephant Seal's annual cycle. They appear also to have seen and hunted them elsewhere; possibly at Juan Fernandez Island (33°S, 77°W) in the Pacific, and described it to Peron during his short visit.

He begins with a brief summary of the discovery and naming of the elephant seal, in which he states that the natives of Port Jackson called it *Mirourong,* from which Gray (1827) derived the current generic name *Mirounga.* The Australian Aborigines, therefore, certainly must have known about the elephant seal long before European settlement; and there are modern records of Southern Elephant Seals occurring on the New South Wales coast today (Llewellyn *et al* 1994).

Péron credits the Dutch with being the first to mention the "sea lion" seen on the island of Juan de Fernandez (Anon 1623 *in* Péron & Freycinet 2003). Linnaeus (1758) gave the Southern Elephant Seal its first name, *Phoca leonina,* with its type locality restricted to Juan Fernandez Island. However, Péron decided to name it as a new species, *Phoca proboscidea* (or Trunk Seal), because of the large pendulous snout of males. He correctly distinguished elephant seals from northern and southern sea lions on the basis of their characteristic proboscis and thick mane, respectively, in males.

Péron rightly believed that the Southern Elephant Seal had a circumpolar distribution on islands lying between latitudes 35°S and 55°S. In Australia it was confined to islands off northwestern Tasmania, especially King Island

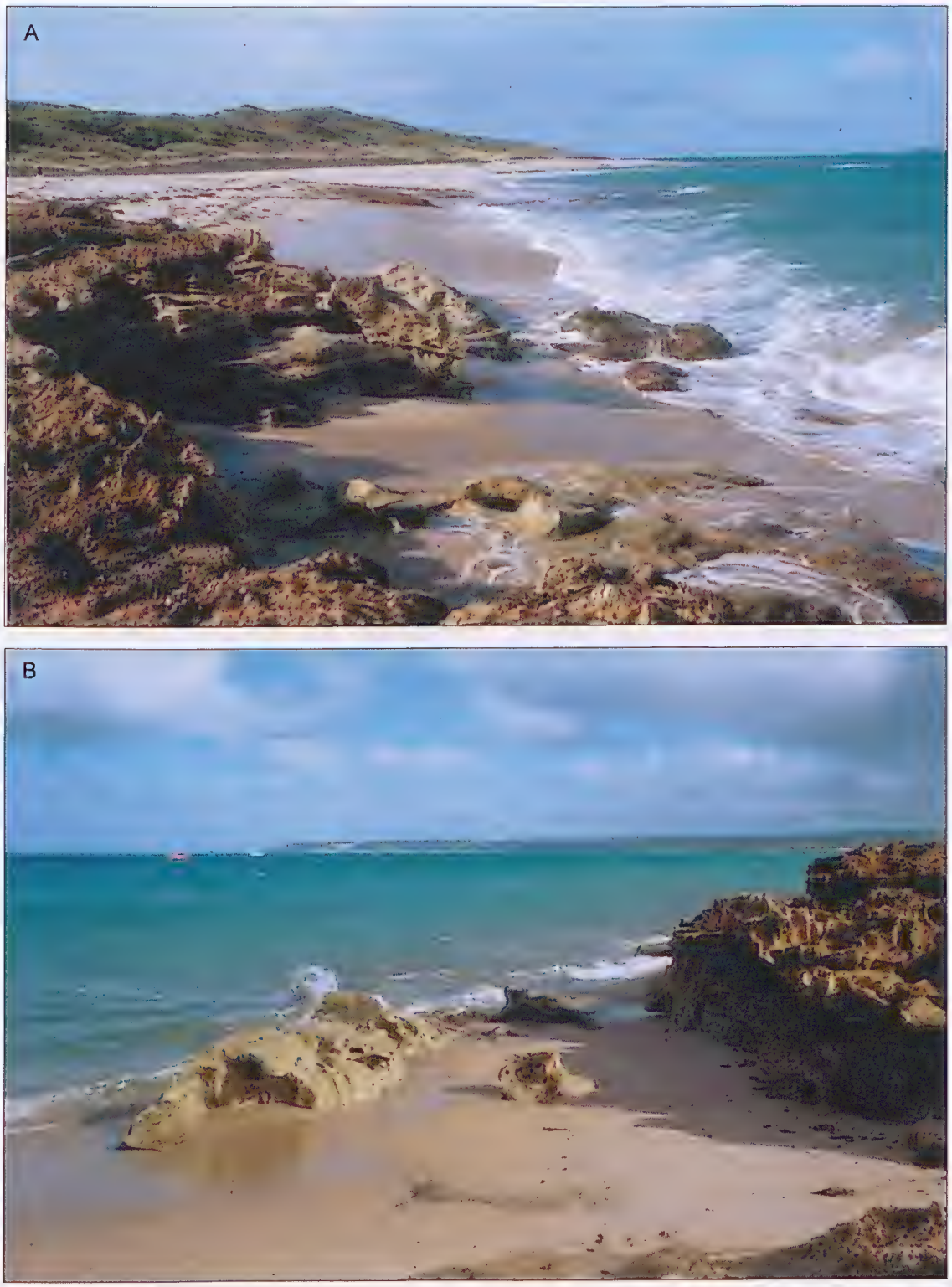

PLATE 1 — Blowhole Beach, Sea Elephant Bay: A, looking north towards Point Cowper, with Sea Elephant Rock (now Councillor Island) showing faintly on the horizon at far right; B, looking south towards Fraser Bluff near where the French scientists' camp is believed to have been located.

and its environs. There is also archaeological evidence that a breeding population of Southern Elephant Seals existed on the northwestern Tasmanian mainland, but was wiped out in prehistoric times by Aboriginals for whom they were an important food resource (Bryden *et al.* 1999). The species possibly also may have ranged as far north as southern New Zealand. In his study into the archaeology of New Zealand sealing, Smith (2002, p. 15, Fig. 6) reproduced a chart made by Eber Bunker, one of the early American whalers in the Antipodes, that shows a small island off the south coast of Stewart Island (43°S) underneath which the word "elephant"' appears. This is possibly a reference to the sighting of elephant seals there – in a similar latitude to that of King Island.

LIFE HISTORY AND POPULATION DYNAMICS

Péron does not say which elephant seals were taken for oil in terms of size, age or sex. Was the "catch" composed of large (immature and mature) males, big animals of both sexes, or all that were available regardless of size? He mentions that some seals were killed with a heavy blow on the nose which, in my experience, would be effective only on smaller animals – certainly not the large males which, according to Péron, were killed by means of a sharp lance driven into the left side, thereby piercing the heart.

When Péron was on King Island during much of December 1802, immature elephant seals should have been ashore undergoing their annual moult, according to what we now know about the annual cycle of this species at sub-Antarctic Macquarie Island (54°S, 158°E) (Carrick *et al.* 1962b, Ling 2012). There should not have been any breeding females or large breeding males present at this time of the year. However, Lesueur's illustration, also of the French scientists' camp at the head of Sea Elephant Bay, clearly shows large males with their pendulous proboscises, as well as what appear to be smaller males sparring on the beach (see Plate 1 in Ling 1999a).

While Péron did not attempt to quantify the population size of elephant seals which he encountered on King Island, there are several references which indicate that the numbers were quite large. In an historical tribute to François Péron in Micco's (1971) translation of chapter XXIII in the 1816 edition of Péron's journal, Louis Freycinet stated (p. 38) that Péron "studied the history of the gigantic seals that assembled in thousands on the shore". Péron himself in Péron & Freycinet (2003) observed that "the shores of this island are all covered with a prodigious number of amphibians" (his term for any animal that lives in or out of water). When the scientific party landed, "the entire head of this (Sea Elephant) bay was covered in elephant seals". However, none of the illustrations in the many publications associated with the Baudin expedition show more than a few seals – and certainly not the prodigious numbers or thousands quoted by Freycinet and Péron. Nevertheless, the quantities of elephant seal oil landed at Sydney and other ports and stated to have come from King Island suggest that a significant population of Southern Elephant Seals did inhabit the island before its discovery and naming in 1801 (see Cumpston 1973; Ling 1999a).

It is difficult to know with any reasonable certainty how big the King Island elephant seal population might have been before it came to be exploited for oil at the beginning of the nineteenth century. The main problems with any attempts to estimate the original numbers lie in not knowing the composition of the "catch" in terms of sex, age and size of the seals taken because of a complete lack of records and the different amounts of oil each class of seal produced. Adult males and some bigger females may have been big enough to deliver useful amounts of oil (Péron stated that a very large male could produce about 140 gallons, or half a ton, of oil). Cumpston (1968), on anecdotal evidence, said that adult males and adult females yielded 0.5 and 0.1 ton of oil, respectively. Hindell & Burton (1988) used oil yields of 180 kg and 70 kg per adult male and female, respectively, from which they estimated that the original elephant seal population at Macquarie Island before sailing began was 93 000 to 110 000. Using the latter figures, Ling (1999a) devised a formula to convert oil quantities to seal numbers and calculated that it took between 10 000 and 17 000 seals to produce 1 100 to 1 300 tons of oil. Another calculation using double the notional numbers of only adult males and females (to allow for numbers of immature seals) required to deliver one year's (1803) lower (460 tons) and upper (563 tons) yields suggests a population of between 11 500 and 14 000 seals. Some 8380 tons of oil were produced at Macquarie Island from 93 000 to 110 000 seals, roughly equating to one ton of oil from 11 to 13 seals, presumably of many sizes. Using these crude figures, the King Island population can be estimated to have numbered between 12 100 to 14 300 and 14 300 to 16 900 animals, respectively. Based on these three methods of calculation, King Island's pristine Southern Elephant Seal population would have been around 15 000. Péron's thousands may have been about right.

It should be noted that, within these figures lies the fact that, while seal hunting was proceeding between 1802 and 1819, the seals were continuing to breed – albeit in ever-decreasing numbers – and replace those that had been killed, until the population was virtually extinct. Macquarie Island's has recovered, King Island's never did.

DESCRIPTION

Péron's description of the Southern Elephant Seal is consistent with much of what we know today, apart from the dimensions he gave for what undoubtedly were adult males, which he stated grew up to 20, 25 or even to 30 feet in length and 15 to 18 feet in girth (6.1, 7.6, 9.1 and 4.5 to 5.4 metres, respectively). The largest male measured at the Falkland Islands (52°S, 59°W) was 20 feet in length, although a slightly bigger one was seen but not measured (Laws 1953). As in many older accounts dealing with the sizes of wild animals, Péron's appear to be exaggerated at the higher end of the scale. Carrick *et al.* (1962a) stated that elephant seals at Macquarie Island, to which the King Island seals may have been related, did not grow quite to the same size as those at South Georgia (54°S, 37°W) – possibly due to the latter lying south of the Antarctic Convergence and, hence, being a true Antarctic island, bringing into operation Bergmann's rule about animal size increasing with closer proximity to the poles and attendant greater cooling. Thus the maximum length of elephant seals at King Island probably would have been about six metres.

One very acute observation by Péron was of the facial vibrissae, two groups of which, the mystacials (whiskers) and supraorbitals (eyebrows), he stated were present on the elephant seal. In fact, there is a third group (rhinals) on the snout (Ling 1966). While he did not enumerate these sensory hairs in their respective groups, he noticed what he termed their "screwed" shape, which has been

described more recently as beaded, bumpy or wavy, and slightly flattened, as opposed to being smooth and round in cross-section as in otariid and some other phocid seals (Ling 1966, 1977, Ginter *et al.* 2010). Péron did not speculate on the possible functional significance of the shape of these prominent hairs or, indeed, the vibrissae themselves, which are still a subject of considerable conjecture. Ginter *et al.* (2010) alluded to three possible functions: drag reduction, increased sensitivity, and reduced interference to environmental, including prey, signals.

Péron remarked on the short, coarse hairs of the elephant seals' coat which rendered it unsuitable as fur, but stated that the hide could be turned into quite good leather for making harness. This was in contrast to the fine pelts of fur seals (probably Australian, *Arctocephalus pusillus doriferus* Wood Jones, 1925 or *A Forsteri* (Lesson, 1828) many thousands of which Péron saw in the sealers' camp, along with barrels of seal oil (see also Ling 1999b).

One relic of the fur seal industry on King Island is what is known as the Sealers' Wall near Surprise Bay at the southern end of the island. It is believed fur seals were driven inland from a small cove to be trapped by the stone wall and then killed and skinned. More than 48 000 fur seal skins were harvested at King Island between 1801 and 1819 (Ling 1999a, 2002).

With his eye for detail, it would be very surprising for Péron not to have seen and commented on the elephant seal's dramatic form of moult – shared only with monk seals – if it had been taking place at the time of his visit to King Island. These seals shed their old fur attached to large ragged sheets of dry, cornified epidermis which peels off rather like sunburnt human skin (Carrick *et al.* 1962b, Ling 1965, 2012). Surely, Péron would have noticed this, but nowhere does he mention this almost unique and dramatic form of moult. Immature elephant seals of both sexes should have been undergoing their annual moult in December, if they were following the Macquarie Island timetable. However, the artist, Charles-Alexandre Lesueur's quite accurate coloured picture (p. 31 in Péron & Freycinet 2003) depicts large male elephant seals showing no signs of peeling skin with hairs attached. Judging by the size of these animals' proboscises, they appear to be approximately of breeding age; which raises the question as to how their presence on King Island in early December may be reconciled with what is known today about their annual cycle.

The sealers found that only the tongue was edible and they avoided eating the liver for reasons unexplained. They possibly were not aware of the high vitamin A content of the liver, as is known today (Southcott *et al.* 1971). Certainly, indigenous people around the world have known for a long time to avoid eating the livers of carnivorous animals that they killed for food.

BREEDING SEASON AND GROWTH

Péron contended from reading other authors that Southern Elephant Seals did not reside permanently on their particular islands but came and went at different times of the year. They were said to migrate from north to south and south to north. The first northern migration was believed to take place in mid-June and the seals arrived at King Island in large numbers at the end of that month. According to the island/s sealers, the shores were covered by them; but which age and sex categories Péron did not record.

Péron stated that, a month after their arrival, the females start giving birth surrounded by males which prevented them from going back into the sea until the end of lactation. At Juan Fernandez Island, according to Péron, the females also go ashore in mid-June to have their young and stay until the end of September fasting all the while; i.e., for 3½ months! These seem rather curious observations, because it is now known that mating takes place just before the end of lactation, soon after which the cows go to sea to recuperate from their four- to five-week breeding fast (Carrick *et al.* 1962b).

Lactation was said by Péron to last seven to eight weeks at King Island after which the females went down to the sea with their pups, in order either to teach their young to swim or to recuperate after the breeding fast; the pups being constantly herded by older seals to keep them close to the shoreline. After three to four weeks at sea the females were said to haul out again for the purpose of mating: fertilisation, said Péron, occurred at the end of September and parturition in mid-July, meaning that, according to Péron's figures, gestation took about 9½ months. Péron did not state how he arrived at the observations cited above; they read as if he was reporting what the sealers had told him. In any case, the life history of *Mirounga leonina* at King Island, as outlined by Péron, differed starkly from what we now know about the species at its various sub-Antarctic breeding sites. Maybe the sealers were reporting what they had observed at Juan Fernandez. Péron, of course, was not at King Island when the elephant seals reputedly were breeding.

At Macquarie Island, breeding bulls (beachmasters) start arriving in early August, followed by the cows towards the end of that month. Pups are born from early September to early November, numbers peaking in early October. The maximum number of bulls is reached in late September and cows in mid-October. The latter are ashore five days before pupping and about 23 days after, lactating. Mating takes place towards the end of lactation. The fat weaned pups spend a further five to six weeks on the island during which time they play in the water and learn to swim, unaccompanied by their mothers. They start to leave in December and all are gone before the end of January. Immature seals are ashore moulting between November and January, adult females moult during January and February, and adult males moult from February to April; some even remaining until early June (Carrick *et al.* 1962b).

We also know today that after mating and fertilisation there is a period of about 14 weeks in which a many-celled blastocyst remains free in the reproductive tract – a phenomenon now termed delayed implantation or embryonic diapause – of which Péron undoubtedly would

have been unaware. Foetal development, according to these figures, thus takes about 8½ months.

Labour was stated by Péron to last five to six minutes, during which time the females appeared to suffer some pain, while the males "look on with indifference". A single pup was produced: sealers are reported to have witnessed only one instance of a twin birth in five to six years of operation (presumably at locations other than King Island) prior to 1802. The fasting females grew thinner and some were seen to die during the pupping season at King Island.

At birth the pup was said to weigh about 70 pounds (32 kg) and measure four to five feet (122 to 152 cm) in length. Carrick *et al.* (1962a) stated that newborn pups at Macquarie Island weigh about 83 pounds (37 kg) and are approximately 50 inches (127 cm) long; they tend to be slightly smaller than pups born at more southerly Signy Island (61°S, 46°W) in the South Atlantic. Péron stated that male pups at King Island were larger at birth than females – although he was not there to see them – which is consistent with the findings at Macquarie Island, where observations were far more detailed (Carrick *et al.* 1962a). He also contended that this trend continued in later generations of pups. Carrick *et al.* (1962a) found that pups at Macquarie Island did not begin to put on weight before they were three to 12 days old (average about six days). Female pups trebled their birth weight in 17 days, males in 18 days at Signy Island (Laws 1953). Growth of pups, according to Péron, however, is so rapid that they gained about 4 feet (122 cm) and 100 pounds (45 kg) in the first week! Péron does not describe how he arrived at these figures; certainly there was no mention of any attempt to weigh or measure pups.

Further growth was said by Péron to be so rapid that young seals (presumably males) reach lengths of 18 to 25 feet (5.5 to 7.6 m) by the end of their third year, which is the normal limit to their size (Carrick *et al* 1962a); he mentioned that from then on they increased only in girth. Péron stated that the sealers believed the Southern Elephant Seal's life span to be about 25 to 30 years. Those figures are slightly inconsistent with what we know today. Two females marked as pups were resighted 23 years later and may have lived another two years (Hindell & Little 1988); and Laws (1953) believed that the maximum age attained by males was 18 to 20 years, based on the study of tooth rings. It was believed in earlier times that elephant seals went inland to die, but this has not been reported in modern writings.

The appearance of the characteristic pendulous proboscis indicated to Péron the attainment of sexual maturity by the large males. It is now known that sexual maturity (i.e., the presence of viable sperm) is in fact reached at three to four years of age, beyond which further physical growth, including the proboscis, takes place; but breeding status is not reached until at least nine to 10 years of age (Laws 1953). Of course, Péron had no means of telling how old harem bulls might have been. He did note, however, or more likely was informed by the sealers, that the harem master dominated in the mating of females, with other (subordinate) males then mating indiscriminately. Mating was reported to last about 12 to 15 minutes.

BEHAVIOUR

Péron also gave a masterly account of the elephant seal's general behaviour. At King Island they were known to cross over sand dunes 15 to 20 feet (4.6 to 6.1 m) high, beyond which there were little pools of fresh water to provide wallows to lie in. I believe, after visiting King Island that Péron may have been referring to what is now known as the Sea Elephant River and its flood plain, inland from the northern end of Sea Elephant Bay (pl. 2). However, the Fraser River at the southern end of the bay could just as likely figure in this behaviour; moreover, the black rutile beach there would be favoured by elephant seals, because of the warm black sand. He noted that elephant seals exclusively hauled out on beaches rather than rocks, which fur seals use, and also remarked upon the seals' habit of scooping up wet sand with their foreflippers and throwing it over their bodies when the weather was hot, as it would have been in December. They slept on sand or in the sea or wallows, while all the time some kept a watch out "in case of danger" but he did not state from what. Their senses, according to Péron, are not very acute; the eyes are adapted more to vision in water than in air, being flat with thick lenses and a possibly viscous vitreous humor.

Their locomotion was described as being slow and laborious, bodies quivering like a huge bladder full of jelly, with frequent stops to rest. No more accurate a description can be found in modern literature.

The elephant seal's habit of swallowing pebbles was also remarked upon by Péron who surmised that this was to maintain tautness of the stomach – towards what end was not stated. However, he too may have been thinking about curbing "hunger pangs", which Shaw (cited by Laws 1956a) suggested in 1801 – a year before Péron's observations – and with which Bryden (1999) agreed. Others today suggest that the stones may assist in digestion, dealing with internal parasites by acting as some kind of grinding mill, or perhaps acting as a sieve to retain larger particles of food, in other species of seals (Needham 1997).

According to Péron, females and young males sound like the bellowing of a vigorous bull, but the adult males' vocalisation resembles more of a loud gargle. This they utter in the course of the many fights during the breeding season, when they compete for mastery of the females. They crash into each other's chest, jaw against jaw, with much blood flowing from the face. Péron believed that the thick layer of blubber prevented contact between any wounds and the air, and also from excessive bleeding. He also noted that elephant seals suffered wounds at sea: from what he did not say, but several species of large toothed whales would be obvious candidates both around the Australian coast and in the sub-Antarctic, while sharks also could well prey on them in Australian waters. Other injuries could be sustained by being dashed against rocks.

Despite the ferocity of agonistic behaviour during the

PLATE 2 — Looking northeast to the mouth of the Sea Elephant River emptying on to Nine Mile Beach. The river mouth is said to have retreated about a kilometre southwards since the early nineteenth century.

breeding season, Péron believed the elephant seal had an "extremely gentle and easy-going nature" and could easily be tamed: citing an instance of a sealer adopting a young one as a pet.

EXPLOITATION AND CONSERVATION

Finally, Péron issued a prescient warning about the consequences of uncontrolled slaughter of marine mammals in general and the Southern Elephant Seals of King Island in particular. While the seal oil industry there lasted from 1802 to 1819, over 80% of oil production occurred in the first four years and 95% in only seven years (Ling 1999a). By that time there were so few seals left that the industry was hardly viable. Today there are no elephant seals on King Island, apart from occasional stragglers which land there and elsewhere around Australia's southern coasts, where pups have been born in southern Tasmania (Pemberton & Skira 1989) and southeastern South Australia (Shaughnessy *et al.* 2012). Péron's prediction sadly was all too accurate: a healthy breeding population no longer exists at King Island.

PÉRON'S LEGACY

For a trainee zoologist in only his early twenties, François, Péron showed remarkable powers of observation of nature, and his colourful and sometimes flowery language does not in any way detract from many of his quite accurate descriptions. Some of the timetables given for various phases of the elephant seal's annual cycle are somewhat contrary to what we know today from many intensive studies at, for example, Macquarie Island. There is a possibility, however, that latitudinal and consequent day-length differences between the two islands may indeed account for at least some differences or discrepancies (see Temte 1991). Furthermore, many of the dimensions given for elephant seals by Péron are very wide of the modern mark; and some of his statements undoubtedly were based on hearsay from the sealers. Notwithstanding these reservations, Péron provides us with a very good account of Southern Elephant Seals at King Island more than two centuries ago and only 14 years after European settlement began in Australia.

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TROPICAL PALMS AND ARUMS AT NEAR-POLAR LATITUDES: FOSSIL POLLEN EVIDENCE FROM THE TAMAR AND MACQUARIE GRABENS, NORTHERN TASMANIA

by Mike Macphail and Greg Jordan

(with one plate)

Macphail, M.K. & Jordan, G.J. 2015 (18:xii)Tropical palms and arums at near-polar latitudes: fossil pollen evidence from the Tamar and Macquarie grabens, northern Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 149: 23–28. ISSN 0080-4703. Department of Archaeology & Natural History, College of Asia & the Pacific, Australian National University, Canberra, ACT 0200 (MM*); School of Plant Sciences, University of Tasmania, Sandy Bay, Tasmania 7005 (GJ). *Author for correspondence: Email mike.macphail@anu.edu.au

We illustrate and discuss fossil pollen evidence for two mostly tropical extant plant families in the Tamar Valley, north of Launceston, northern Tasmania, and the Macquarie Harbour Graben on the west coast of Tasmania. These are palms (Arecaceae) producing disulcate pollen (*Dicolpopollis* spp.) and an incompletely zonisulcate pollen (*Proxapertites* cf. *operculatus*) identified as a fossil arum (Araceae). Both fossil pollen types add to the growing body of evidence that warm to hot conditions allowed tropical monocots belonging to these two families to grow at high palaeolatitudes (c. 65°S) during the Late Paleocene and/or Early Eocene in Tasmania and even closer to the pole (c. 70°S) during the Late Cretaceous in central and southern mainland Australia.

Key Words: Fossil palms, arums, Arecaceae, Araceae, *Dicolpopollis*, *Proxapertites*, Late Cretaceous, Late Paleocene, Early Eocene, Tasmania, southern and central Australia.

INTRODUCTION

Palms (Arecaceae) and to a lesser extent arums (Araceae) are archetypal indicators of extant tropical environments, and fossil occurrences of palm pollen in particular have been used as evidence for warm to hot conditions at high palaeolatitudes in both hemispheres in the past (see Mai 2000). A key taxon is the tropical mangrove palm *Nypa*, a genus that achieved a nearly worldwide distribution during the Eocene (references in Gee 2001), consistent with episodes of methane-induced global warming (hyperthermals) during the Early Eocene (see Zachos *et al.* 2008). *Nypa* fruits, fronds and/or pollen (fossil equivalent *Spinizonocolpites prominatus*) have been found in Paleocene to Early Eocene sediments in the continental margin basins around Australia, including in the Early Eocene Macquarie Harbour Beds at Strahan on Tasmania's West Coast (references in Pole & Macphail 1996, Dowe 2010). The latter are part of a growing body of evidence for near-tropical mean air temperatures (MAT) within the partially occluded gulf separating Australia and Antarctica at a palaeolatitude of c. 65°S (Carpenter *et al.* 2012). Conditions at this latitude include several months of winter darkness and, at present, subzero MATs.

In this Extended Abstract, we illustrate and discuss two fossil pollen types (*Dicolpopollis*, *Proxapertites* cf *operculatus)* preserved in Late Paleocene and Early Eocene sediments, respectively, infilling the Tamar Graben north of Launceston and Macquarie Harbour Graben near Strahan. These fossil pollen have close morphological affinities to modern pollen produced by tropical members of the Arecaceae and Araceae families (see Hesse *et al.* 2001, Hesse & Zetter 2005, 2007). Unlike *Nypa*, corresponding macrofossils have not been found. The specimens are part of a plexus of fossil arecoid and aroid morphotypes (see Table 1 in Harley & Baker 2001) found in marine and terrestrial sediments in Australia that range in time from the Campanian to the Plio-Pleistocene and in space from Tasmania to the North-West Shelf. Late Cretaceous morphotypes are not described in this paper but examples are illustrated in pl. 1, e.g., Maastrichtian specimens of *Proxapertites* cf *operculatus* and *Arecipites* Wodehouse 1933 emend Nichols *et al.* 1973 from the Bundey Basin in Central Australia, and Cenomanian specimens referred to *Mauritiidites* van Hoeken-Klinkenberg 1964 and *Nuppharipollis* Krutzsch 1970 from the Bight Basin off the coast of South Australia. Two palm (*Archontophoenix*, *Livistona*) and two arum (*Alocasia*, *Gymnostachys*) genera extend as far south as c. 33–35°S along the central and south coasts of New South Wales but other genera are mostly confined to Queensland and the Northern Territory (see Hnatiuk 1980).

LOCATIONS

The geological setting and Cenozoic evolution of the N–S orientated Tamar Graben, now partly occupied by the Tamar Estuary in northern Tasmania, and Macquarie Harbour Graben near Strahan on the West Coast of Tasmania have been reviewed by Carpenter *et al.* (2012) and Forsyth *et al.* (2014). The fossil arecoid/aroid pollen morphotypes were recovered from (a) a sequence of carbonaceous silts at 179.20–291.8 m depth in the Bell Bay BH-1 corehole (487717.6167mE 5446018.027mN MGA: RL 39.5 m) drilled at Bell Bay near the mouth of the Tamar River (Macphail 2014a) and (b) carbonaceous mudstones at 184.1 m depth in Strahan STR-BH1 (358300mE, 5335100 mN MGA RL 38.2 m) drilled behind Ocean Beach at Strahan. Both coreholes were drilled by the Tasmanian Department of Mines (now

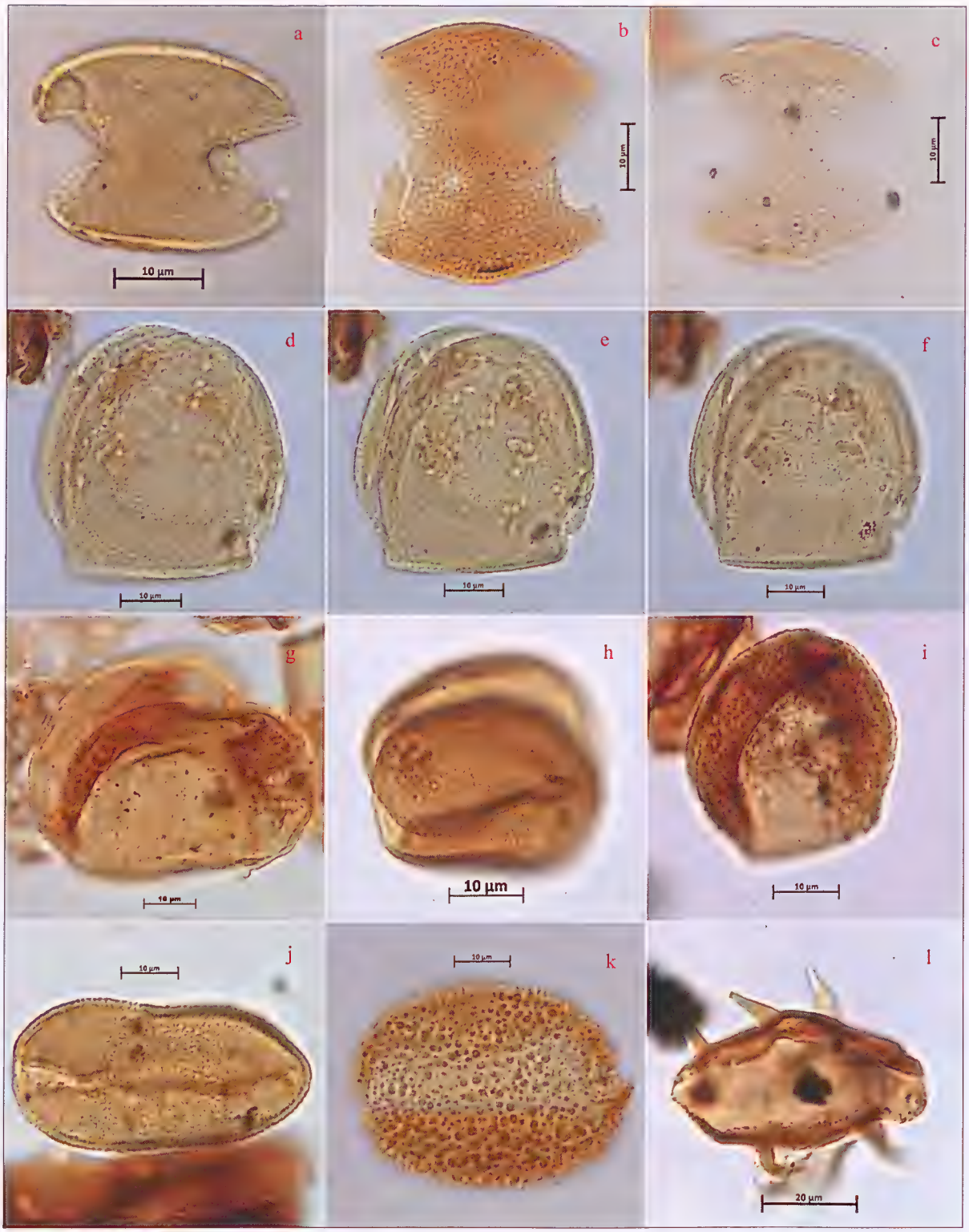

PLATE 1 – a: *Dicolpopollis* sp. Bell Bay BH-1 287 m, Tamar Graben, northern Tasmania. Specimen in polar view (Late Paleocene). b: *Dicolpopollis* sp. Geoscience Australia dredge sample GAB SS012007/21DR13 B5.1, offshore Bight Basin, southern Australia. Specimen in polar view (Cenomanian). c: *Dicolpopollis* sp. Geoscience Australia dredge sample SS012007/22DR14 D3, offshore Bight Basin, southern Australia. Specimen in polar view (Cenomanian). d: *Proxapertites* cf *operculatus* Bell Bay BH-1 179.30–179.33 m, Tamar Graben, northern Tasmania. Specimen in equatorial view (Early Eocene). e: *Proxapertites* cf *operculatus* Bell Bay BH-1 179.30–179.33 m, Tamar Graben, northern Tasmania. Specimen in equatorial view (Early Eocene). f: *Proxapertites* cf *operculatus* Bell Bay BH-1 179.30–179.33 m, Tamar Graben, northern Tasmania. Specimen in equatorial view (Early Eocene). g: *Proxapertites* cf *operculatus* Strahan STR BH-1 184.1 m, Macquarie Harbour Graben, western Tasmania. Specimen in equatorial view (Early Eocene). h: *Proxapertites* cf *operculatus* Santa Teresa ST4 73.25–73.28 m, Santa Teresa Basin, Central Australia. Specimen in equatorial view (Early Eocene). i: *Proxapertites* cf *operculatus* HUC-11 102.45–102.54 m, Bundey Basin, Central Australia. Specimen in equatorial view (Late Maastrichtian). j: *Arecipites* sp. HUC-11 102.45–102.54 m, Bundey Basin, Central Australia. Specimen in proximal polar view (Late Campanian-Early Maastrichtian). k: *Mauritiidites* sp. HUC-11 96.00–96.03 m, Bundey Basin, Central Australia. Specimen in proximal polar view (Maastrichtian).l: *Nupharipollis* sp. Geoscience Australia dredge sample SS012007/28DR20 A5.1, offshore Bight Basin, southern Australia. Specimen in proximal polar view (Cenomanian).

Mineral Resources Tasmania) in the early 1980s. Bell Bay BH-1 intersected a discontinuous sequence of conglomerates, sands and silts deposited in a series of freshwater fens during the Oligocene, Early Eocene and Late Paleocene (Late Thanetian). The Cenozoic infill (Launceston Beds) includes a number of thin cemented ferruginous intervals (ironstones/ferricretes) and unconformably overlies Jurassic dolerites at 293.6 m depth. Sediments deposited in the Macquarie Harbour Graben underlie Late Quaternary sand dunes at Ocean Beach and outcrop in sea cliffs southwards along the eastern shoreline of Macquarie Harbour. Subaerially-exposed marginal marine strata demonstrate the infill (Macquarie Harbour Formation) has undergone down-to-basin (en-echelon) faulting during separation of Australia and Antarctica in the Late Cretaceous and Early Paleogene, followed by uplift, due to tilting of the Australian continent during the Neogene and Quaternary (see Pole 1998, Corbett 2003, Quigley *et al.* 2010). Strahan STR BH-1 intersected a c. 165 m thick interval of middle to late Early Eocene sediments (Macquarie Harbour Formation) overlying a dolerite conglomerate at c. 364 m depth. Palynostratigraphic analysis of weakly-lithified organic-rich clays, sands and lignites show the interval between 184.1–289.0 m depth was deposited in freshwater swamps whilst abundant *Spinizonocolpites prominatus* and marine dinoflagellates, confirm the interval between 346.5 and 349.0 m depth accumulated in a tidal estuarine environment (Macphail & Partridge 2012).

AGE CONTROL

The age control is based on the time distribution of fossil pollen and spore species (morphospecies) in the Bass, Gippsland and Murray basins (Macphail 1999, Partridge 1999, 2006,), with additional local control provided by sites elsewhere in Tasmania to Central Australia (see Macphail 1997, Macphail *et al.* 2014). Basalts at and above 19.6 m in Bell Bay BH-1 have not been independently dated. Marine dinoflagellates provide independent age control for Strahan BH-1 (see Macphail & Partridge 2012, Carpenter *et al.* 2012).

FOSSIL POLLEN

The fossil arecoid and aroid pollen types are illustrated in pl. 1. We emphasise that the Tamar and Macquarie Harbour Graben specimens are **not** formally described in this paper because of (a) the paucity of *Dicolpopollis* specimens and (b) the strong probability the Tamar and Macquarie Harbour specimens of *Proxapertites* can be accommodated in the formally described morphospecies *P. operculatus* Van der Hammen 1956. Pollen morphological terms follow Harley & Baker (2001) and Punt *et al.* (2007).

A. *Dicolpopollis* Pflanzl 1956 emend Ediger *et al.* 1990

Fossil pollen referred to the morphogenus *Dicolpopollis* are distinguished by two sulci that usually are parallel to each other and which sometimes converge or even touch on the short side. The outline (amb) is symmetric ellipsoid ("bobbin-shaped": Harley & Baker 2001) in polar view and irregularly elliptical to trapezoidal in equatorial view. The pollen wall (exine) is two-layered, relatively thick and ornamented with vermiculate, rugulate or reticulate sculptural elements. Individual grains (monads) are usually flattened along the meridional plane and the aperture, a sulcus, is usually seen as notches on the equator in the equatorially flattened grains. The size range was not specified in the formal description of the morphogenus (see Card 4230 in Jansonius & Hills 1985).

Tamar Graben: A disulcate pollen morphotype recorded 287.0 m (Late Thanetian) in Bell Bay BH-1 (pl. 1a) conforms closely to the generic description although the specimen, orientated in polar view, is too poorly preserved to determine if the ornamentation is psilate, reticulate, verrucate or granulate.

Comment: Calibration points for molecular dating of the genus level palm phylogeny indicate that extant palm lineages initially diversified in a tropical rainforest-like biome at about 100 Ma (Late Albian) at northern latitudes in Laurasia (Couvreur & Baker 2015). The earliest unequivocal palm macrofossils are early Late Cretaceous (see Harley 2006). According to the website maintained by the Russian Academy of Science (palaeobotany.ru/index.php), some 25 pollen fossil species (morphospecies) of *Dicolpopollis* have been formally described, which range in age from Middle Albian to Pliocene. These equatorially disulcate grains are considered to be fossil members of the subfamily Calamoideae, with particular morphospecies referred to extant genera (Harley & Baker 2001). For example, microreticulate and foveolate morphotypes assigned to *Dicolpopollis kockelii* Pflanzl 1956 ex Potonié 1966 and *D. metroxylonoides* Khan 1976 are considered to be fossil representatives of the rattan palm *Calamus* and sago palm *Metroxylon*, respectively (see Harley & Baker 2001). For the same reason, significant relative abundances are considered to be reliable evidence for moist tropical climates, e.g., Lelono (2012). Fossil *Dicolpopollis* specimens in Australia have not been consistently recorded but illustrated records include (a) a number of described and undescribed *Dicolpopollis* spp. from Cenomanian sediments on Bathurst Island, north of Darwin in the Northern Territory (pl. 32 figs 8–10 *in* Norvick & Burger 1976), (b) the microreticulate species *D. bungonensis* from Middle Eocene deposits on the Southeast Highland of New South Wales (fig. 5 A–D, G–I in Truswell & Owen 1988) and (c) specimens compared to *D. metroxylonoides* in Early Eocene to Late? Miocene sediments in the Murray-Darling Basin (fig. 7G in Truswell *et al.* 1985, pl. 4 fig. 8 in Macphail 1999). The earliest records of the morphogenus we know of in southern Australia occur in Cenomanian (*Hoegisporis uniforma* Zone) sediments in the Bight Basin (Appendix 3.1 in Totterdell & Mitchell 2009). One of the fossil morphotypes (pl. 1b-c) resembles pollen produced by the

tropical Asian to west Malaysian rattan palm *Plectocomia elongata* (cf. figs 29–31 *in* Harley & Baker 2001).

B. *Proxapertites* Van der Hammen 1956 emend Singh 1975

Fossil pollen referred to the morphogenus *Proxapertites* are circular to subcircular in shape, and zonisulcate with a tectate exine. Since the sulcus is more or less parallel to margin, the pollen grain often breaks into two approximately equal halves. Ornamentation varies from none (psilate) to granulose, punctate, microfoveolate or reticulate (see Card 4322 *in* Jansonius & Hills 1985).

The type species *P. operculatus* Van der Hammen 1956 is described as radially symmetrical but slightly anisopolar since the grains are separated by a continuous equatorial colpus into two slightly unequal parts; oblate and rounded angular to oval in polar view; colpus ectexinous, somewhat irregularly bordered by a narrow indistinct margin of thinning exine, columellae indistinct , 1 µm long , < 0.5 µm thick, covered by a <1 µm thick finely reticulate-perforate tectum, lumina 1 µm wide, smaller along margins of colpus, muri 0.5 µm wide, < 1 µm high. 36–61 µm and variable in shape (see Gemeraad *et al.* 1968). Individual grains range in size from 20–70 µm in height and 25–50 µm in length. The clam-shell or hamburger-shaped amb view distinguishes *Proxapertites operculatus* from the ellipsoidal to trapezoidal-shaped foveolate to reticulate morphospecies assigned to *Longapertites* van Hoeken Klinkenberg 1964 (see Jansonius & Hills 1985: Card 4282; pl. 5 figs 13–6 *in* Schrank 1994).

Tamar Graben: Pollen grains, which appear to be identical to illustrated specimens of *Proxapertites operculatus*, occur in low numbers (relative abundance 2%) at 179.30–179-33 m (midlate Early Eocene) in Bell Bay BH-1 (pl. 1d–f, Macphail 2014a). For example, the specimens are zonisulcate with an irregular very fine reticulate sculpture. However, the Bell Bay BH-1 specimens differ from the formal diagnosis of *P. operculatus* in that they are incompletely zonisulcate and the columellae along the sulcal margins are distinctly visible. Whether these differences are sufficient to exclude the Tamar Graben population from *P. operculatus* is unclear but this seems unlikely given the broad range of sculptural morphotypes accommodated within this morphospecies and very wide distribution of fossil records of the morphospecies in geologic time and space (see Muller 1968, Jamarillo & Dilcher 2001, Hesse & Zetter 2007, Lelono 2007).

Macquarie Harbour: Records of *Proxapertites* cf. *operculatus* in the Macquarie Harbour Graben consist of several grains recovered from a middle Early Eocene claystone with coalified macrofossil remains at 184.1 m depth in Strahan BH-1 (pl. 1g, Macphail 2014b). Despite the distorted state of preservation, these grains possess the same key morphological characters as the Tamar Graben specimens, viz. an irregular very fine reticulate sculpture and the presence of granules along the margin of the zonisulcus.

Comment: Harley & Baker (2001) and Harley (2006) interpret *Proxapertites operculatus* (and *Longapertites*) as a fossil arecoid whose nearest living relative (NLR) is the tall palm genus *Areca*, found in humid tropical forests from China and India through Malesia to tropical Australia. The arecoid affinity has been strongly challenged by Hesse *et al.* (2001), Zetter *et al.* (2001) and Hesse & Zetter (2005, 2007) who conclude the morphospecies is most probably an ancestral member of Araceae subfamily Monsteroideae and/or subfamily Zamioculcadoideae, comparable to pollen of the modern genera *Monstera*, *Gonatopus* and *Zamioculcas*. Unlike *Areca*, these genera range in stature from herbs growing from tubers and rhizomes to evergreen vines, have modern distributions centred in eastern Africa and the tropical Americas, and include drought-tolerant and deciduous species. Monosulcate pollen of probable monocotyledonous origin first appear in the Early Cretaceous (see Friis *et al.* 2010) but, as far as is known, the only previously illustrated *Proxapertites* specimens (incorrectly referred to *Longapertites*) in Australia come from Early Eocene lacustrine sediments in the Cenozoic Santa Teresa Basin in Central Australia (figs 4–5 *in* Macphail 1997).

DISCUSSION

On present indications, the Arecaceae and Araceae evolved during the Early Cretaceous and may have achieved a worldwide distribution during the Late Cretaceous (Hesse & Zetter 2007, Baker & Couvreur 2013, Couvreur & Baker 2015). The fossil pollen record for individual morphospecies, however, is more varied in time and space. For example, fossil pollen assigned to *Proxapertites operculatus* have a pantropical (predominantly Gondwanan) distribution, with Cretaceous records including the Barremian–Aptian in Portugal, (see fig. 3 *in* Friis *et al.* 1994) and the Maastrichtian in Africa and the Caribbean. During the Cenozoic, the morphospecies is at its most frequent in the Paleocene to Early Eocene in northern South America, but is restricted to the Eocene in Europe.

When palms and arums first reached Australia is less clear because of the patchy nature of the fossil record in the epicontinental basins, all of which have been subject to widespread erosion and/or deep weathering, and in the continental margin basins, especially those on northwestern and northern margins, which have suffered sediment starvation during and since the Late Cretaceous. Assuming *Arecipites*, *Dicolpopollis*, *Mauritiidites* and *Nuppharipollis* specimens from the Central Australian and the Bight Basins represent arecoid lineages, then palms were present in southern Australia during the Cenomanian, a period when this region (Great Australian Bight) was at a palaeolatitude of c. 70°S (see Veevers *et al.* 1991). By Campanian-Maastrichtian time, potential fossil arecoid pollen also include a range of undescribed psilate, baculate, gemmate and verrucate monosulcate morphotypes preserved in independently-dated marine sediments in the offshore Bonaparte Basin, west of Darwin, and offshore Browse Basin on the west coast of Western Australia (Macphail 2007). The earliest known specimen of *Proxapertites* is a poorly preserved specimen in a Maastrichtian fen sediment intersected at 102.45–102.54 m depth in the HUC-11

corehole drilled by the Northern Territory Geological Survey in the Bundey Basin, Central Australia (pl. 1i).

In contrast, the earliest known record of fossil *Nypa* pollen (*Spinizonocolpites prominatus*) comes from independently-dated Paleocene sediments in the Carnarvon Basin off the central west coast of Western Australia (Macphail 2007). Both *Spinizonocolpites* and *Proxapertites* appear to reach their maximum abundance during one or more of the Early Eocene hyperthermals (see Zachos *et al.* 2008), albeit in different settings. For example *Spinizonocolpites prominatus* has been restricted to paralic environments in the continental margin basins around Australia (see Partridge 1976, Pole & Macphail 1996) whilst Cenozoic populations of *Proxapertites* cf. *operculatus* have been recorded only in fluvio-lacustrine deposits in Central Australia and northern and western Tasmania. *Dicolpopollis* spp. are more widely recorded in marine and non-marine facies but, except for a Middle Eocene site on the Southern Highlands of New South Wales (Truswell & Owen 1988), only occur in trace numbers.

Although these fossil pollen records are an unreliable basis for tracing migration pathways across Australia, our data suggest palms were well-established around the continental margins of Australia during the Late Cretaceous and thereafter became established inland when and where regional conditions were suitable during the Paleogene. For example, *Spinizonocolpites prominatus* became extinct in southeastern Australia in the relatively cool early Middle Eocene (Partridge 1999, 2006) although *Nypa fruticans* populations retain a toehold on the Coburg Peninsula near Darwin in Tropical northern Australia. Nevertheless our finding that Late Cretaceous arecoids were tolerant of seasonally cool climates is not that surprising given that even now one species, *Rhopalostylis sapida*, ranges as far south as 43°45'S (Banks Peninsula) and 43°54'S (Chatham Islands) in New Zealand and another species, *Livistona mariae*, survives in the geographic centre of the arid zone in Australia (Finke Gorge National Park) at 24°12'S, c. 138 km west of Alice Springs. The presence of Araceae at high palaeolatitudes is more surprising since 90% of genera and c. 95% of species are restricted to the tropics in South America and South East Asia. The importance of the Tamar Graben records therefore is not that palms and arums were present in Australia during the Paleogene but the apparent rapidity with which the Araceae (and *Nypa*) were able to migrate southwards to near-polar latitudes at a time (Early Eocene) when the continent was separated from Antarctica except for the narrow rift valley complex linking Tasmania to East Antarctica via the South Tasman Rise. Whether the arecoids and aroids reached Australia via Antarctica or from the north is unknown.

NOTE ADDED IN PROOF: Since this Extended Abstract was prepared, significant numbers of *Proxapertites* cf *operculatus* [4% of total dryland pollen count] have been recovered from lignite at 84–87 m depth in the water drillhole NTGS Ayers Rock RN 10598. The presence of *Stereisporites maastrichtiensis*, *Proteacidites amolosexinus* and *Tricolpites lilliei*, confirm an Upper *Forcipites longus* Zone Equivalent age for this interval and demonstrate a population of aroids (Araceae) was growing along a palaeovalley near Uluru in central Australia during the Late Maastrichtian.

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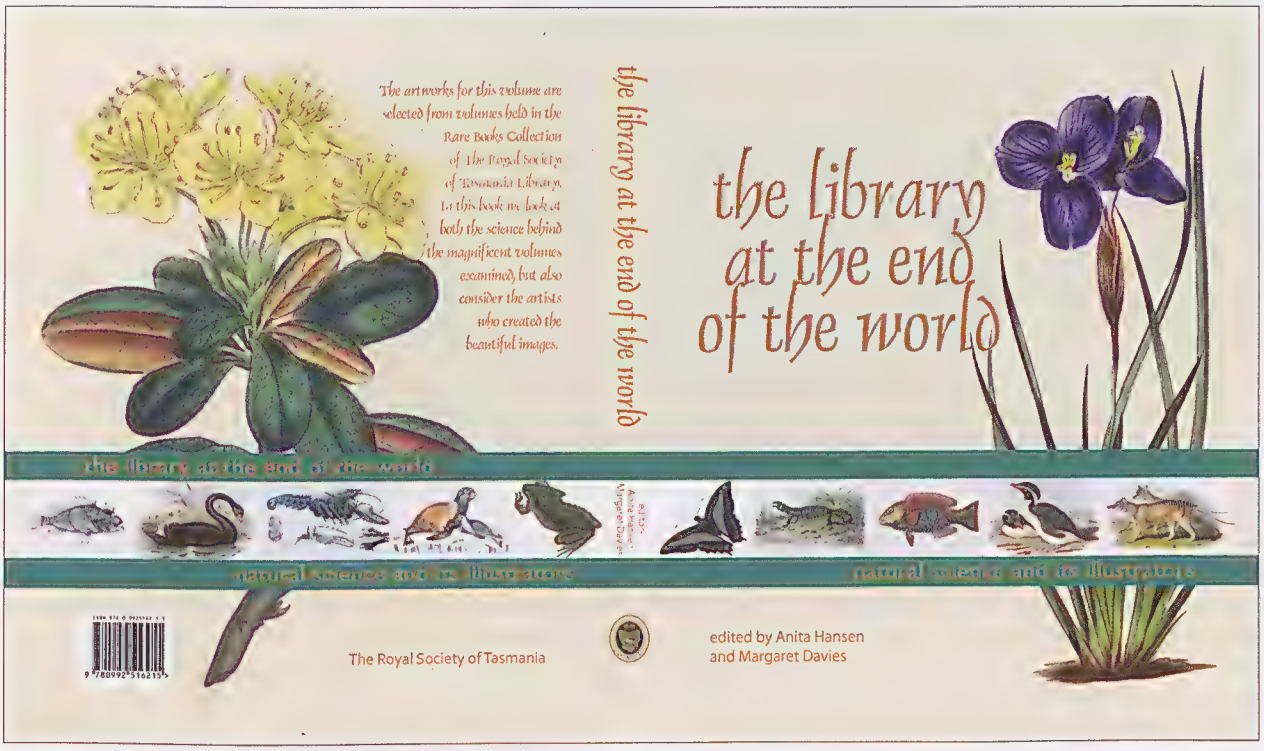
BOOK REVIEW

by Peter J. Jarman


The art works for this volume are selected from volumes held in the Rare Books Collection of The Royal Society of Tasmania Library. In this book we look at both the science behind the magnificent volumes examined, but also consider the artists who created the beautiful images.
the library at the end of the world
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natural science and its illustrators
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Many Australians learn in primary school about European discovery and exploration of Australia; fewer learn how scientific discovery continued after settlement. Among the early settlers of Tasmania were men and women intrigued by the biology of this new land. Their desire to place Tasmania's biota in a world context induced a flow of specimens from the colony to authoritative taxonomists in Britain and continental Europe. Very soon the naturalists wanted to identify and classify for themselves, requiring a reverse flow of books and journals. In the 1830s Ronald Campbell Gunn was sending plant specimens to Sir William Hooker at Kew, and requesting botanical books in return, writing that such books "are not to be procured here at any price". This may soon have been less necessary; the Royal Society's copy of Robert Sweet's (1827-8) *Flora Australasica* carries a bookplate of "W. Westcott Bookseller and Circulating Library, 60 Collins St. Hobart Town", a business that had existed since at least 1845.

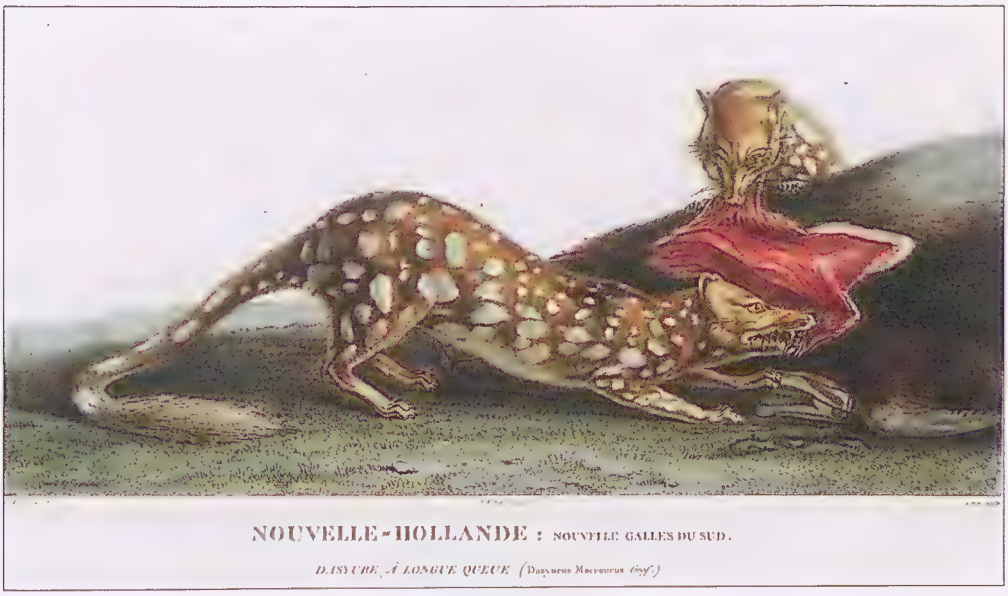
The Royal Society of Tasmania (RST), the oldest scientific society in Australia and New Zealand, was founded in 1843 and quickly established its own library. In 1845 the Lieutenant-Governor of Van Diemen's Land wrote to the Royal, the Antiquarian and the Linnean societies in London, of which he was a member, seeking books for the RST's library. By 1849 the collection held 250 volumes. As the Society grew, the library acquired books more purposefully, emphasising Tasmanian natural history but keeping abreast of national and international publications. In its first century the library was the major public source of natural history knowledge in and about this remote intellectual outpost. *The Library at the End of the World* reviews and illustrates some of the library's treasures. For anyone with a feel for the history of Australian science, this book is a wonderful reminder of the age of discovery in a new land with almost everything yet to be discovered. The library grew during the greatest age of developments in biological illustration; and this book's editors and authors have clearly enjoyed selecting informative and beautiful pictures from the library's holdings.

John Gould and Henry Constantine Richter, Tasmanian echidna (*Echidna setosa*) [*Tachyglossus aculeatus setosus*, Short-beaked Echidna]. Hand-coloured lithograph, 34.5 x 52.0, Gould, J. 1863: The Mammals of Australia. Vol. I, Pl. 2.

Tasmania was important to European appreciation of Australian biota because of visiting, as well as resident, collectors. To quote Peter McQuillan in his chapter on Insects: "Remote Van Diemen's Land was to become a fabled destination for early European naturalists. The discovery of its peculiar creatures … reinforced the emerging appreciation of Tasmania's biological novelty." For example, John Gould's first stop in Australia in 1838 was Van Diemen's Land, where local enthusiasts such as the Franklins, Reverend Thomas Ewing and Ronald Gunn welcomed him. In five months Gould collected 500 Tasmanian birds, naming half of the state's endemic species. He visited Bass Strait islands "where he was greeted by Aboriginal women performing a traditional Emu dance" (quoted from Sally Bryant's chapter on Birds). Tasmanian Aboriginal people and cultural practices continue; the island-state's emu, an endemic subspecies, even then sadly depleted, was extinct in the wild a few decades later.

In sometimes subtle, sometimes total ways, Tasmania's biota differed from those of the mainland. This is illustrated in Stewart Nicol's chapter on Mammals with pictures from Gould's *The Mammals of Australia* (1863): the Thylacine has been unique to Tasmania for many thousand years, while the deeply-furred Tasmanian subspecies of the echidna can be contrasted with its mainland conspecific with exposed spines. This chapter includes two early-nineteenth-century pictures of Eastern Quolls in NSW, where the species went extinct in the 1960s. In Tasmania it survives, a reminder

Sarah Stone, *Rana caerulea*, Blue Frog [*Litoria caerulea*, Green Tree Frog]. Hand-coloured copper engraving, 22.8 x 17.8, White, J. 1790: Journal of a Voyage to New South Wales: ...



Charles-Alexandre Lesueur, Dasyure à longue queue (*Dasyurus Macrourus*) [*Dasyurus maculatus*, Spotted-tailed Quoll]. Hand-coloured lithograph, Péron, F. 1817: Voyage de Découvertes aux Terres Australes ... Atlas par MM. C.a. Lesueur et N. Petit.

of Tasmania's luck in having escaped or delayed the wave of extinctions of medium-sized mammals that, on the mainland, began in the first half of the nineteenth century and continues to the present day.

The taxonomists and illustrators in Europe who worked from pressed, dehydrated, pickled and stuffed specimens produced some bizarre misinterpretations of Australian reality. Margaret Davies illustrates this in her chapter on Amphibians. The Green Tree Frogs shown in White's 1790 *Journal of a Voyage to New South Wales* are pathetically distorted, as poorly curated pickled specimens would be on arrival in Europe. Moreover, the frogs are shown bright blue, and were named Blue Frog in English and *Rana* (now *Litoria*) *caerulea* Latin, because, as Davies points out, no scientist then knew that these handsome green creatures turned blue in preservative.

Most of *The Library at the End of the World* consists of taxon-specific chapters by authorities on vascular plants, orchids, lichens, crustaceans, insects, fishes, amphibians, reptiles, birds, and mammals. None of the chapters pretends to be exhaustive of the taxa, the library's books or their illustrations; each reflects its author's choices, producing varied but always lively accounts. Anita Hansen has written short vignettes of 37 featured artists. The text is tightly edited and the whole book is superbly designed and produced. The book's opening history of the library describes its dynamic support of the state's scientific life up to and beyond the library's 1968 move to the Morris Miller Library of the University of Tasmania. Digital access to catalogues and publications here and around the world is the latest step for those wanting to share the world's natural-history knowledge guided by this library at the end of the world. Anyone who enjoys the history of science (or of libraries) and the development of biological illustration will be stimulated by this book. And every sale of this modestly priced book carries the work of The Royal Society of Tasmania further into its third century.

Peter J. Jarman is Emeritus Professor of Ecosystem Management from the University of New England. He now lives in Tasmania where he is an Associate of the University of Tasmania. His research is in the areas of mammalian ecology and behaviour coupled with a strong interest in scientific illustration from medieval times.

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Book:

Davison, A. C. & Hinkley, D. V. 1997: *Bootstrap Methods and their Application.* Cambridge University Press, Cambridge: 592 pp.

Edited work:

Marchant, S. & Higgins, P. J. (eds) 1993: *Handbook of Australian, New Zealand and Antarctic Birds. Volume 2: Raptors to Lapwings.* Oxford University Press, Melbourne, Australia: 1048 pp.

Chapter in an edited work:

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Thesis:

Charleton, K. J. 2002: Variation in Sooty Shearwater burrow entrance density, burrow use and chick emergence: Science and Traditional Environmental Knowledge approaches. Unpublished MSc thesis, University of Otago, Dunedin.

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Chiswell, S. M. & Rickard, G. J. 2006: Comparison of model and observational ocean circulation climatologies for the New Zealand region. *Journal of Geophysical Research* **111**: C10011, doi:10.1029/2006JC003489.

Website:

IUCN 2001: *IUCN Red List of Threatened Species 2001 Categories & Criteria (version 3.1)*, www.iucnredlist.org (accessed 22 January 2007).

Report:

MacKenzie, D.I. & Fletcher, D. 2005: Characterisation of seabird captures in NZ fisheries. Report to Ministry of Fisheries for Project ENV2004-04. April 2006. Unpublished Report to the Ministry of Fisheries, Wellington: 99 pp.

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